PRODUCT
ENGINEERING

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Shall Inventions Be Regulated?

Fulton's steam boat was a folly. The Wright brothers were harebrained and the first aviators were merely circus performers at county fairs. Faraday's demonstration of electric induction was nothing but a toy in the eyes of Prime Minister Pitt, and that is what people thought of the early Bell telephone. The first automobiles were ruled off the streets of Detroit and any one who at that time would have predicted speeds of 75 miles an hour, super-speed highways, traffic signals, filling stations and national automobile shows would most likely have lost his vote, have had a guardian appointed to handle his estate and have found himself relegated to an asylum. Man cannot predict the future.

But evidently some learned people are still of the opinion that by gathering data and getting a precise knowledge of present conditions they will be able to plan for future scientific progress and development.

Elsewhere in this number will be found a brief resume and discussion of the report "Technological Trends and National Policy" recently issued by the federal National Research Committee. In brief this report recommends, among other things, the creation of a National Resources Board to chart probable trends for the guidance of government and business so that by long-distance planning (20 years is mentioned) the "shock" of major inventions on labor, capital and society may be cushioned. Thus by forecasting the effects of great inventions, scientific progress will be planned. A joint government committee is to be formed to watch and report on technological unemployment. And what would be the next step? Apparently—government supervision of new inventions and throttling them where it was deemed desirable.

Who is to do the throttling of scientific progress? Where are the supermen who will sit as judge and jury to decide the destiny of a great invention? Usually an invention is not great until it has already had a tremendous effect on society. Till then it is a toy, folly, or circus stunt. A plea is made in the report for previsions to forecast the "damages" by new inventions to displaced industries. But where is the great mortal who can see through the curtain that screens the future? Even if such a supernatural one existed, no one would believe him.

But there is one redeeming feature. This scientific progress control idea did not come along soon enough to save industries such as horse shoes, carriages, oil lamps, letter presses, pot-bellied coal stoves and hand sweepers.

Thus we who have all the modern conveniences which put out of business thriving industries of 20 to 40 years ago can feel thankful that such planning was not in effect a century ago. If we stand for the throttling of invention proposed by Mr. Roosevelt's National Resources Committee we can look forward to the dubious satisfaction of telling our grandchildren of the good old days when invention was free and open to every citizen who had an idea for something better. Perish the thought!

Projection welding a caster socket on a washing machine leg

DESIGNS AND PREPARATIONS

For Resistance-Welded Parts

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Importance of, and advantages that can be gained from, the use of various design kinks and preparations, such as the common projection, on metal parts to be resistance-welded

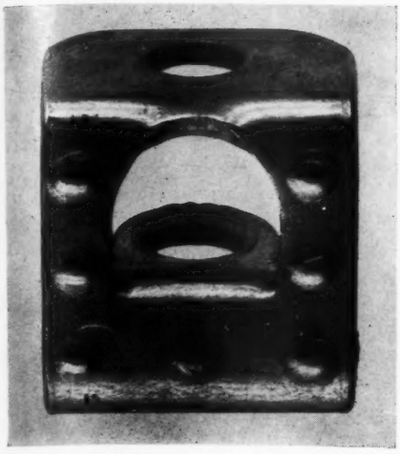
THOUGHTFUL DESIGN and ingenious preparation of metal parts can make practical the use of resistance welding on parts for which it was heretofore considered unsuitable. There are, in fact, hundreds of welding applications being done today that a few years ago were turned down as impossible of accomplishment.

For instance, in handling parts made of heavy steel stampings or forgings, where spot-welding points were out of the question, it is now possible to localize the heat and pressure by a swaged projection, or by a specially forged or coined-on boss, and to pass the welding current through a long circuit of the metal part some distance from the point at which the weld is to take place. The new welding machines, with comparatively large transformers and fast-operating current controls, drive the current through the metal to the point of weld in a time short enough so that relatively little heating occurs anywhere except at the point of welding

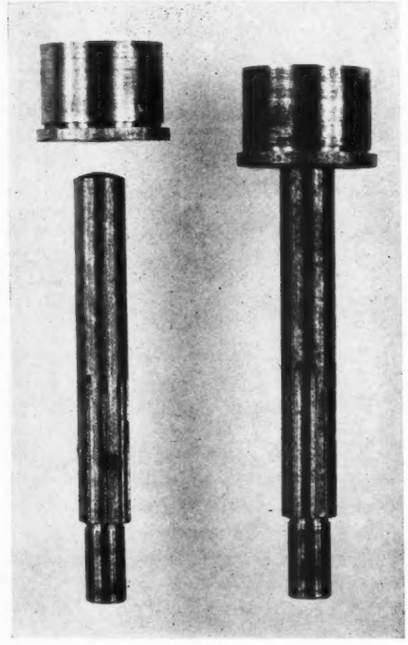
The preparations which help to make such welds possible are usually highly specialized to suit some particular condition in each instance, so that it is difficult to give anything more than a hint as to what can be done generally. Nevertheless, in this article there will be suggested certain elements which should be worked into, or at least considered for every design of parts for welding. In addition, there are given, beginning on page 360 of this number various preparations which can often be incorporated in a design to make it a more successful welding application.

However, because of the great diversity of products welded and types of welding used in the many industries now employing this method of fabrication, the following discussion must be limited to remarks of a somewhat general nature and will be confined largely to projection welding as one of the most widely applicable branches of the resistance welding art.

In the half century that has elapsed since Prof. Elihu Thomson applied for basic patents on the resistance-welding process, it is interesting to note that the greatest advances have been made in the past ten years. Even in the last five years there have been introduced more improvements in welding machines, with corresponding increases in the widespread application of their benefits,



Six projections on the caster socket weld it to the leg of the washing machine



Washing-machine wringer-roll drive shaft is crowned to permit projection butt-weld to driving cup. Parts are held to within 0.006 in. of concentricity

than during any other period in the history of the art. However, the designing of parts to suit welding has probably contributed at least as much as the improvement of the equipment toward creating a new era in resistance welding.

Dependable Welding

Careful designing and preparation of parts have promoted sound welding conditions so that the process is now as foolproof as any other up-to-date machine process. Here it should be pointed out that many engineers are still of the opinion that welding is not dependable. They say that there is no visual inspection possible and that the success of a welding application depends on the human element or skill of the operator. This might have been a qualified attitude some years ago, but with the recent improvements in preparation, technique and equipment, it no longer is reasonable.

By the use of embossings, projections, and other preparations on the parts, the heat and pressure are localized at the places of welding under conditions which do not vary as did the older schemes of spot-welding, wherein a constantly changing copper point or die was depended on. Moreover, the modern welding machines consistently duplicate their function of automatically applying the proper measured heat and pressure at the exact moment required in the welding cycle.

Preparations Now Practical

Thus, conditions are now such that it is thoroughly practical in a plant utilizing any quantity of welding to adopt the principle of preparing all production articles, except very light-gage parts, which would otherwise be spot-welded, with projections or the equivalent and using nothing but the new automatic machines. It is true that sometimes on short-production-run parts it may appear cheaper to turn the welding over to a skilled operator on a manual-type machine, but greater supervision, inspection and other expenses may more than offset the apparent saving.

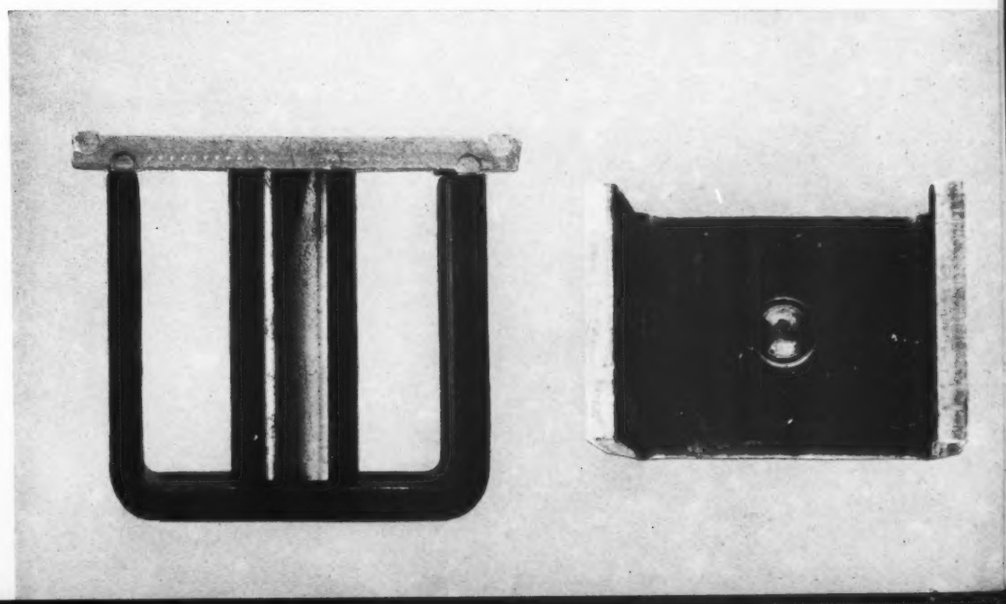
The modern welding machines are equipped with improved mechanical drives; air-cushion and mechanical spring-pressure devices; automatic hydraulic control apparatus; and electric time-control devices, such as motor-controlled relays for operating contactors and, for assuring the greatest accuracy in timing the thyratron control. These new machines are very flexible in their adjustments and, with their precise indicators of pressure, heat, and time, can be readily logged so that duplicate set-ups can be accomplished from time to time if required—a particular advantage on short production runs requiring frequent changes of jobs in machines.

In many instances, the joint or union between parts may be made by one of several types of welding. There is, of course, a tendency to select that kind of welding for which the plant has equipment. However, many applications of welding on a product result in savings great enough to warrant a substantial investment in a new welding machine more suited to the job than the present equipment. In a general way, therefore, it is suggested that the most suitable form of the process be insisted upon. After all, the success of the resistance-welding process in a plant often depends on the engineer doing everything in his power to see that the simplest and most satisfactory form of welding is used, and he should make as few concessions as possible to the tendency of trying to do a job by an obsolete method or on an obsolete machine.

Preparations

With modern equipment at his command, the engineer is offered almost infinite possibilities in the use of preparations on the metal parts themselves to open and reopen opportunities for welding. One instance of how ingenious preparation can solve a difficult problem

Lower set of side projections punched up on top plate of this radio loudspeaker subassembly weld it to electromagnet yoke as shown. Upper set are used later to weld cone housing to subassembly. Yoke has embossing with ring-like crater sunk in around it to permit magnet core's being welded down in intimate contact with yoke surface



is the metal radio tube. A vacuum-tight weld was desired to seal the base cup to the upper drawn-shell envelope. An annular ring-like projection on the base cup was incorporated in the design and its effect made the vacuum-tight weld possible.

Other examples of such preparations will now be discussed, references to figures being to those reproduced on pages 360 and 361. Many of the preparations shown on those pages, however, are sufficiently explained by their captions and therefore will not be discussed in this article.

The preparation commonly known as the "projection" appears in several forms, the simplest and most common being shown in Fig. 1. It is necessary to have a crown or dome in order that the weld may start as a point contact and have a continuously increasing cross-section to the finish of the weld. The size of the projection is determined by the strength required, the number of projections used, kind of material and desired degree of freedom from marking, and size and space available for welding. No definite rule can be given; each design must be based upon the particular factors controlling it. However, a few suggested sizes are given in the accompanying table. Care should be taken that the punch is of the right size and is round-nosed so as not to partially shear out a slug. If the parts to be joined are of different sheet thickness the embossing should be placed on the heavier of the two thicknesses. Figs. 2 and 3 show modifications of the simple projection.

Other Preparations

A "prick punch" projection is illustrated in Fig. 4. The rim thrown up around the punch mark serves as a suitable projection for the welding of very light material to a heavier piece which carries the punch mark.

When studs and screws are to be butt-welded to a surface, a dome should be provided, as shown in Fig. 6, to cause the weld to start at a point and progressively increase in section. A shoulder behind the head is always handy to give bearing for the welded electrode. If studs are straight without this shoulder, then it is necessary to clamp the stud rigidly in an electrode.

Stock Thickness	*Projection Height, in.*	*Diameter, in.*
22 ga.	0.035	1/8
20 ga.	0.035	9/64
18 ga.	0.030	5/32
16 ga.	0.030	3/16
14 ga.	0.033	3/16
12 ga.	0.050	3/16
3/16 in.	0.055	7/32
1/4 in.	0.055	9/32
3/8 in.	0.055	5/16
1/2 in.	0.063	7/16

Sizes of common projection suggested for different thicknesses of stock

The design in Fig. 7 is similar to that in Fig. 6, but is intended to represent heavier combinations. The mere doming of a shaft end is not sufficient alone to butt it successfully to another surface which is part of a heavy section. It is necessary to have an extremely high current density for a very short length of time, such as might require thyratron control, in order to heat the heavier piece up sufficiently to weld and still not upset the shaft.

An annular type of projection often put on screw-machine parts is illustrated in Fig. 9. Such a projection is also stamped into a pressed-steel part, as was done on the metal radio-tube base previously mentioned. It is suited only to the welding of light-gage material. In heavier forms, it heats irregularly and is not as satisfactory as the dome type of preparation.

Illustrated in Fig. 10 is a projection brought up on a heavy piece of material and having a crater-like ring coined in around it. The purpose of the groove is to take any fused or upset metal and to allow intimate contact between welded surfaces.

A scheme used for bringing a projection up from the side of a heavy section is shown in Fig. 11. The projection is made by striking the edge of the part with a punch the face of which is half on the stock and the other half overhanging the stock.

How a cold-headed part may have ribs or any other suitable preparation forged on it to facilitate welding is shown in Fig. 12. The countersunk hole in this instance is used for location as well as to give good bearing to the flat-head screw.

A cross-elongated projection combination used on 24-gage and lighter sheet is shown in Fig. 13. This crossing of elongated projections facilitates welding. Fig. 14 illustrates a practical application of this principle in the welding of handles to tinned oil drums. Here, however, the projections are ribs crossing at right angles.

Most designs and preparations necessarily have to be a compromise between the ideal for welding, the available equipment, and the final utility or appearance of the product. On these points, the designer is cautioned to lean backward and favor the welding requirements as much as possible. The examples of preparations given here will serve as suggestions, but it is still up to the ingenuity of the engineer to cope with a difficult application and work out something which will satisfactorily localize heat and pressure to cause the desired weld.

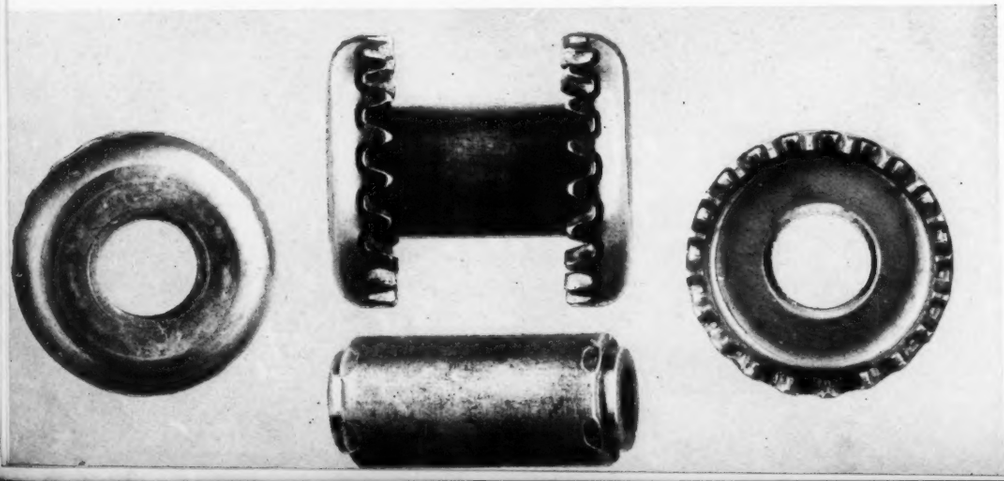
Production Considerations

In connection with the designing and preparing of parts for welding, the engineer should consider the possibility of incorporating production-time-saving devices, such as making multiple welds simultaneously, employing principles of self-locating parts, and using fast-operating jigs and fixtures.

The projection, in its several forms, is about the only dependable device that will permit a multiplicity of welds to be made at one time. On light-gage sheet the series or shunt weld can be used to advantage in speeding up the welding operation. Then, too, the engineer should always consider the possibility of welding two or more units of a small assembly at one time.

Ingenious methods of making parts self-locating by the use of half-punches, locating ribs, tabs, etc., may reduce handling time enormously by eliminating the use of jigs. However, if jigs and fixtures appear necessary, the parts designer should keep in mind the problems of the fixture designer. The parts should be so made that they may be removed from the machine easily after being united, and possibly an extra hole or two should be provided to facilitate jigging. Where possible, all spot welds should be laid out so that they can all be made with one setting of the machine.

Projection-welding two cord hooks at once to washing-machine legs



Product Developments

Recessed Base, Automatic Oil Feed, and Built-in Controls

Thought and care in the location of the various elements in the design of a machine are exemplified by the No. 5 plain grinder recently announced by Brown & Sharpe Mfg. Co. Although the electric controls and the oil reservoir and pump for the automatic lubrication system are in the base of the machine, nevertheless these elements are so located as to permit recessing the base so that the operator can sit comfortably while at work. Despite this feature, the overall dimensions have been kept down, and as shown in Fig. 1, a neat, compact appearance was achieved.

The lubrication system is interesting in that a plunger pump, driven by an eccentric on the table-driving mechanism, delivers oil to the cross-feed screw and nut and to a reservoir beneath the spindle, into which ring oilers dip to lubricate the spindle bearings. As shown in Fig. 2, overflow from the spindle reservoir oils the other bearing surfaces and mechanisms. Since comparatively little oil is needed, movement of the table at even its slowest rate will pump an ample quantity, thus automatically providing proper lubrication during operation.

Although headstock, table, wheel, and coolant pump are driven by separate motors, one main pushbutton station starts and stops the whole machine. The magnetic controls and individual motor-overload relays, as shown in Fig. 3, are grouped in a base compartment at the right side of the machine. Thus built-in, they are well protected, yet easily accessible.

Another interesting feature of this machine is an arrangement by means of which the headstock and coolant pump are automatically started by rotation of the cross-feed handwheel to feed the grinding wheel toward the work, and stopped when the handwheel is turned to withdraw the grinding wheel. This is accomplished by a pilot switch which is actuated when the handwheel is rotated, thus operating a magnetic contactor which starts and stops the two motors. This feature, together with a headstock brake, contributes to high productivity.

Convenient arrangement of the cross-feed controls, adjacent to main pushbutton, is shown in Fig. 4. The amount of automatic cross feed is determined by the setting of the variable-radius crank mechanism, shown to the right of the handwheel, with cover open.

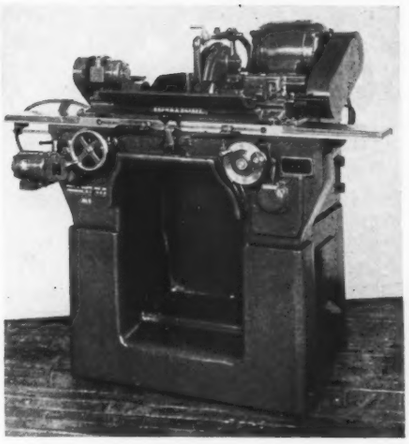


Fig. 1 — Recessed base for this plain grinding machine permits operator to sit comfortably while at work

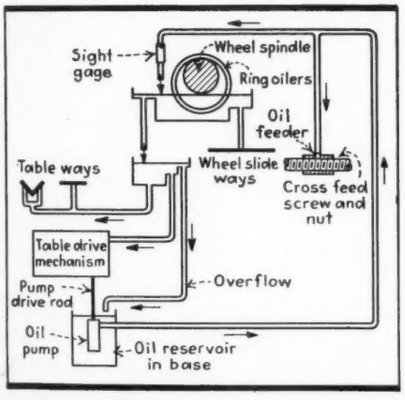


Fig. 2—Diagram of lubrication system

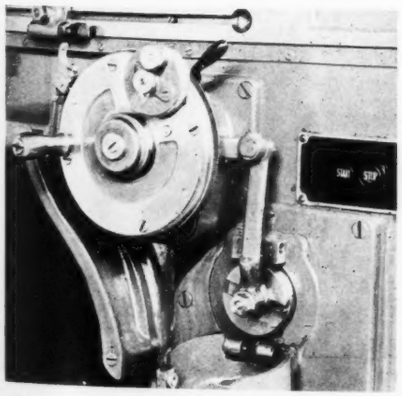
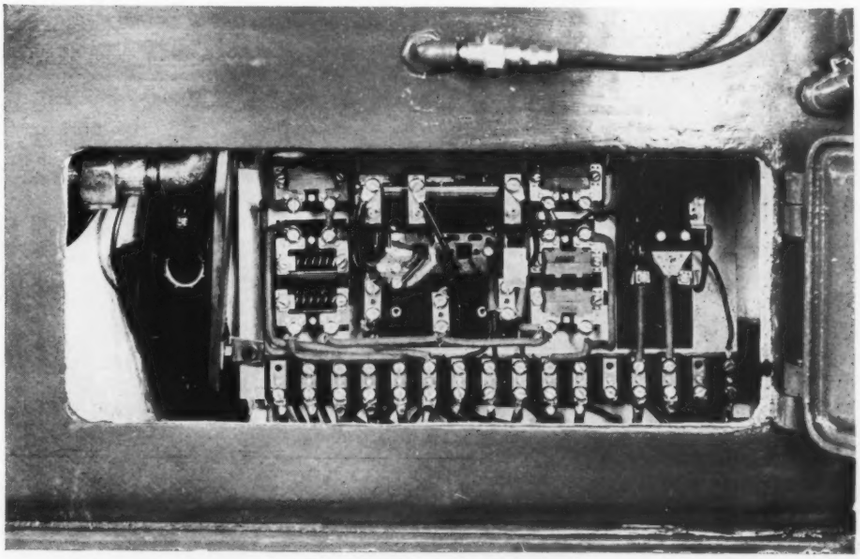


Fig. 4—Convenient arrangement of cross-feed controls

Fig. 3—All electric control units are built-in



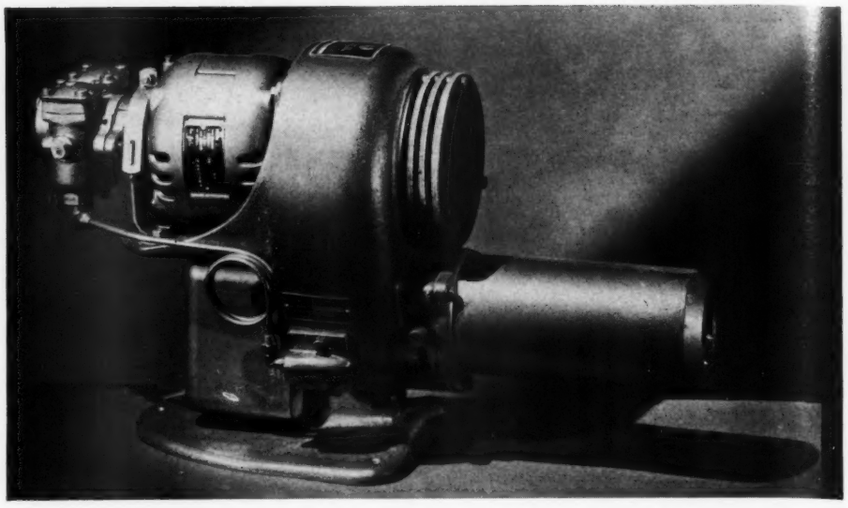
Strikingly Styled For Appearance

Measures taken recently by three progressive manufacturers to dress their products in a style contemporary with the modern materials and mechanical features employed in the designs are here illustrated. The appearance-styling of all three of the new designs is simple and unaffected and no artificial devices are employed to "soup up" any inherently undesirable details. And they have character; they look their part.

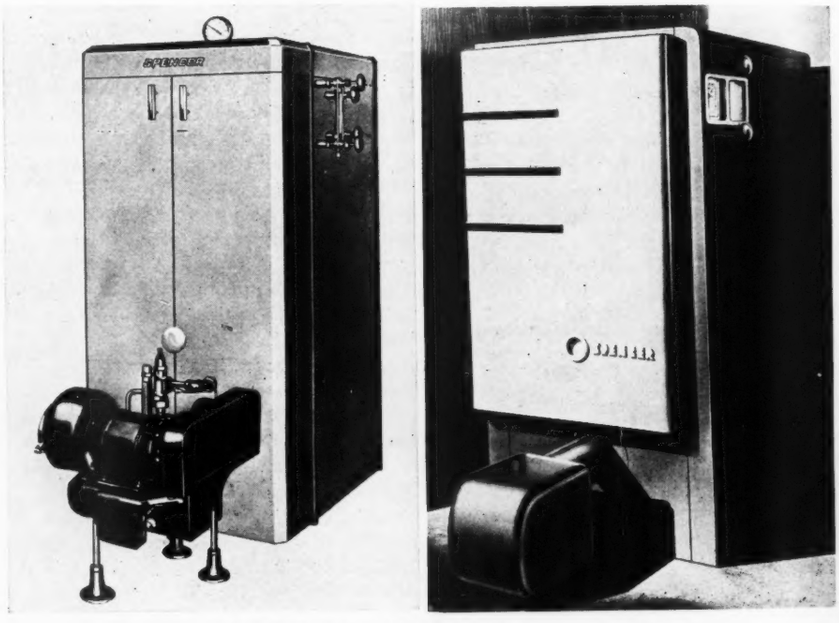
In this respect the oil burner made by the Heil Company, Milwaukee, Wis., is particularly frank and unassuming. Functional almost to the point of severity, it nevertheless achieves a pleasingly distinctive appearance, and does it in such a straight-forward, business-like manner that prospective customers should be duly impressed at a single glance. Among its mechanical features are bayonet-type connectors which slide into transformer coil contacts and a hinged transformer which affords ready access to the complete firing-head assembly.

The new design of oil-burning furnace, styled by Gilbert Rohde for the Spencer Heater Company, presents an interesting contrast with the old. In this treatment, one of the problems was to develop a design that would be sufficiently different from that of other units on the market as to make it noticeable but which would not be so different that the consumer would have to be re-educated to accept it. Production costs, too, were given careful consideration with the result that the cost of fabrication is materially lower for the present jacket than for an intermediate redesign of the old jacket undertaken with this factor in mind.

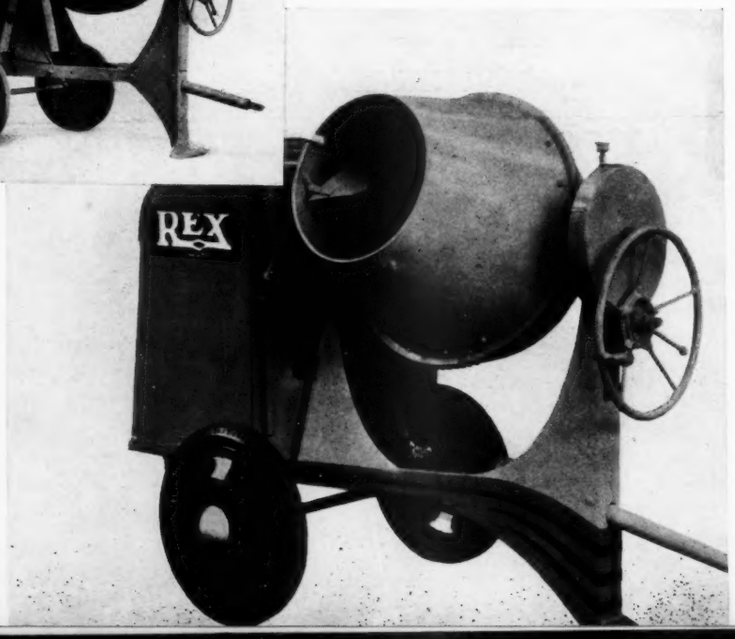
In the strictly industrial field, the new tilter cement mixer, designed by Wilbur Henry Adams for the Chain-Belt Manufacturing Company, exemplifies what can be done toward improving product appearance without making other than minor changes. Comparison of the "before" and "after" views will reveal that the only fundamental change is in the treatment of the sheet-metal engine housing, which now has a more pleasing contour sloping toward the rear. Other effects were obtained with paint alone.



The Heil oil burner presents a pleasingly straight-forward, business-like appearance



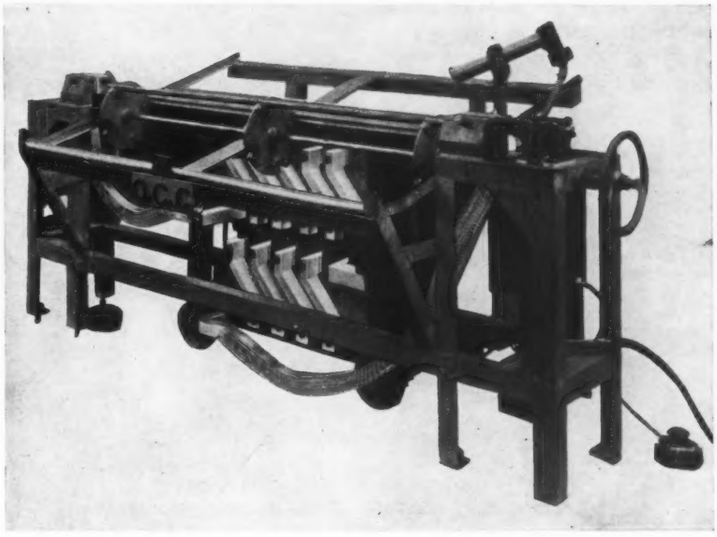
The new and old Spencer oil-burning furnaces exemplify how a product can be distinctively styled and yet not depart so far from conventional design as to require consumer re-education



A new contour for the engine housing and a more judicious use of paint represent the difference between "before" and "after" designs of Chain-Belt "Rex" cement mixer

Photoelectric Trip Mechanism for New Electric Bar Heater

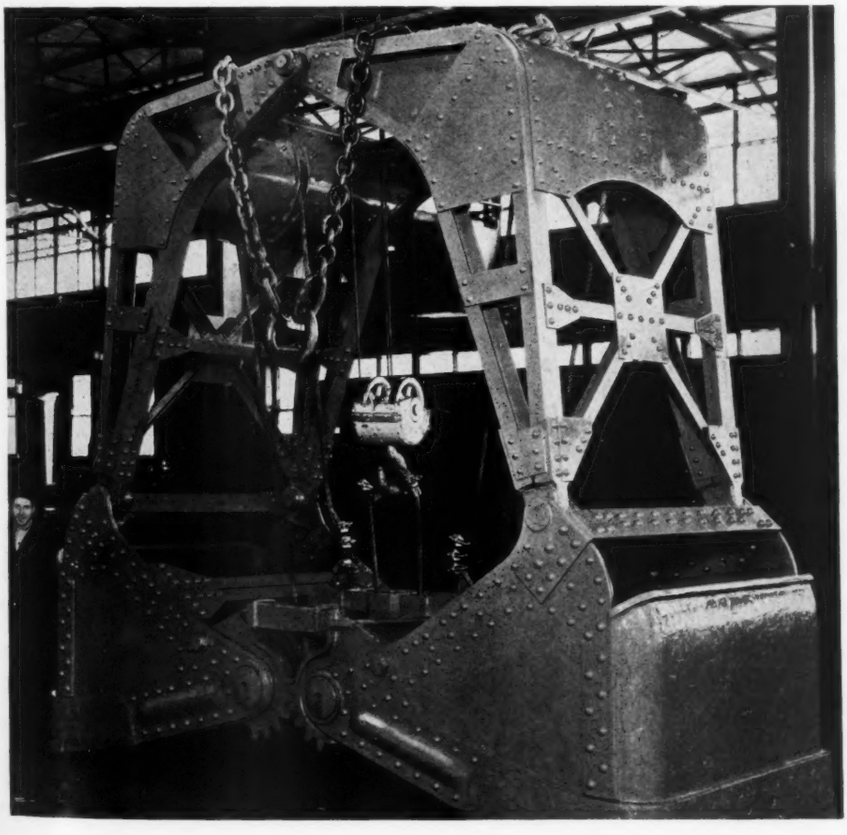
Through the action of a photoelectric relay, bars being heated in the A.C.F.-Berwick 6-ft. bar heater are automatically disconnected from the electrodes upon reaching the desired temperature. The phototube "watches" the bar and, when the proper color temperature is reached, the relay actuates a solenoid-operated valve which controls an air cylinder. The cylinder withdraws one of the electrodes from the bar, in effect tripping the circuit. Operating on the resistance principle, the machine will heat 1-in. diameter bars, 6 ft. long, to 2,000 deg. F. in 75 sec. or less



New-Design Clam-Shell Bucket

Especially designed to meet the unusual conditions existing at most skull-cracker pits in steel plants is a new-type two-line clam-shell bucket recently built by the Blaw-Knox Company. Like the ladles and magnets also used in these locations, the new bucket operates from a travelling crane with two hooks arranged in a plane at right angles to the tracks carrying the cars but, unlike conventional two-line buckets so suspended, its jaws then work in the proper position for dumping broken slag into the cars.

Two-line clam-shell bucket, of sturdy construction, especially designed for use in steel-plant skull-cracker pits



The bucket is picked up by both the main and auxiliary crane hooks. One hook picks up a chain sling which is attached to the bucket head and the other hook picks up the operating line. With the two cable drums spaced at 3 or 4 ft. there is no fouling of the lines.

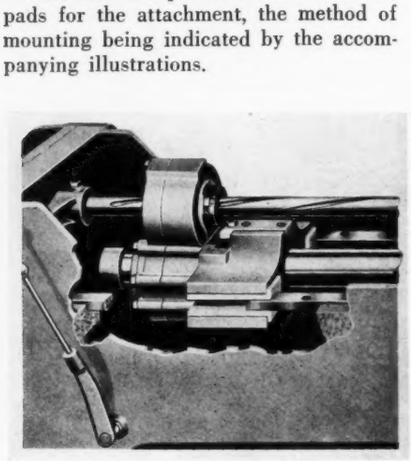
Weighing 22,000 lb., the bucket is of sturdy construction. The jaws and trays are made of chrome-nickel-molybdenum steel, heat-treated so that it is able to retain its properties in the presence of hot slag. The material has a tensile strength of 100,000 lb. per sq. in. and has a Brinell hardness at the cutting edge of 350. The scoop side-plates are made of alloy steel of 80,000 to 90,000 lb. per sq. in. tensile strength. Hinge and corner castings are made of nickel-vanadium steel with the main hinge pins of chrome-nickel heat-treated steel S.A.E. 3140. Sealed anti-friction bearings are provided for all sheaves, and high-tensile bronze bearings of 250 Brinell hardness are used for the hinges.

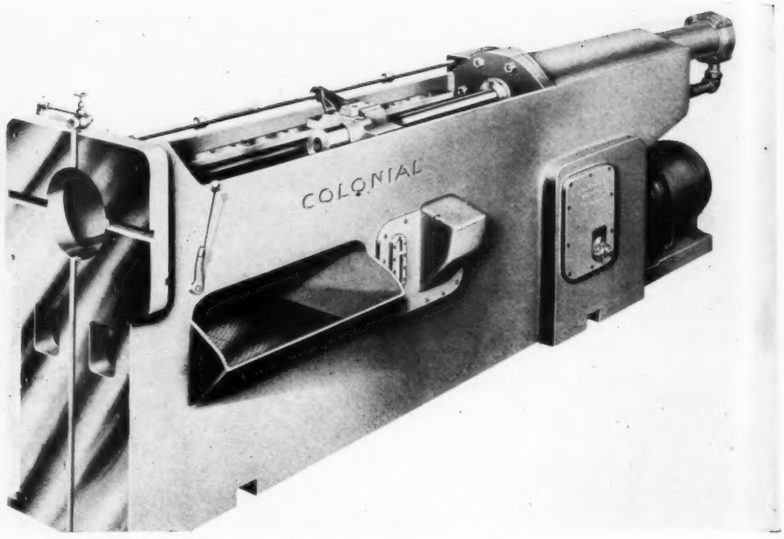
Spiral Broach Drive

For broaching internal helical splines, either straight or involute, a spiral drive attachment has been developed for use with the Colonial Broach Company's recently introduced all-purpose broaching machine. The attachment utilizes a rigidly mounted spiral master bar which, through gears, causes the broach to rotate as it passes through the work.

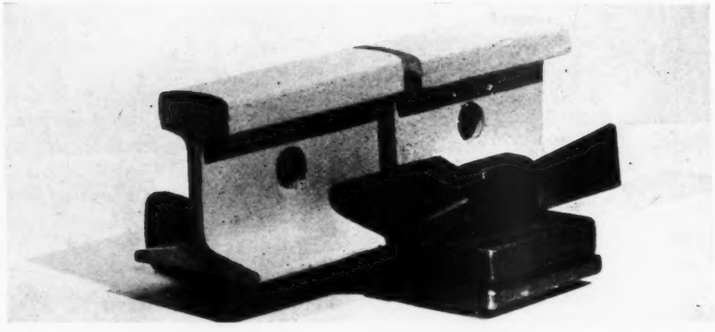
The device is said to produce the correct helical lead in the finished part with greater accuracy, eliminate side thrust

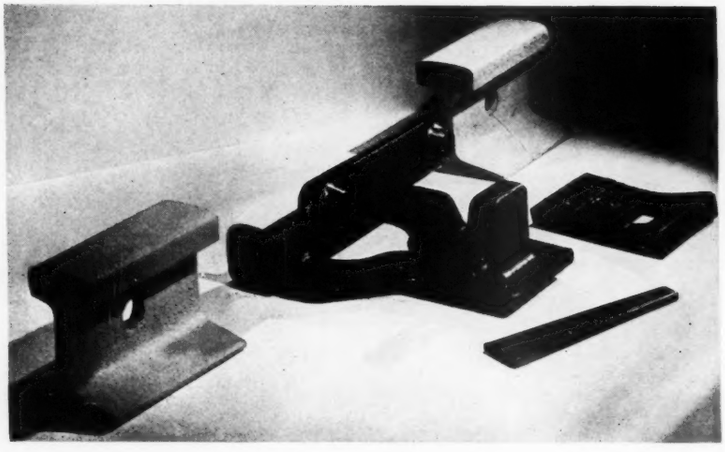
and drag on the sides of the splines, and increase broach life. All sizes of the machine are provided with mounting pads for the attachment, the method of mounting being indicated by the accompanying illustrations.





New broaching machine on which spiral drive attachment, shown in cutaway close-up, can be mounted for broaching internal helical splines





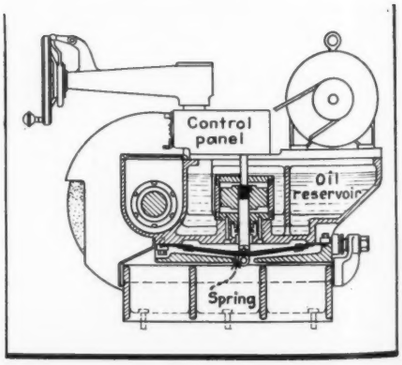
Simple Splicer Needs No Bolts

Ease and speed of applying a new splicer for coal-mine tracks is gained through the use of a wedge design instead of a design requiring bolts, nuts and fishplates. Recently announced by the Portable Lamp & Equipment Co., Pittsburgh, Pa., the splicer consists of only three parts, as shown by the accompanying illustrations. Malleable iron is used for the parts in order to obtain resistance to corrosion and shock and to secure castings with smooth surfaces true to pattern

Spring-Toggle Grinding Feed

A leaf spring acting as a toggle produces the slow-grinding-feed motion in the "Bowgage" independent grinding-wheel head unit manufactured by the Fitchburg Grinding Machine Corporation. The spring is located horizontally

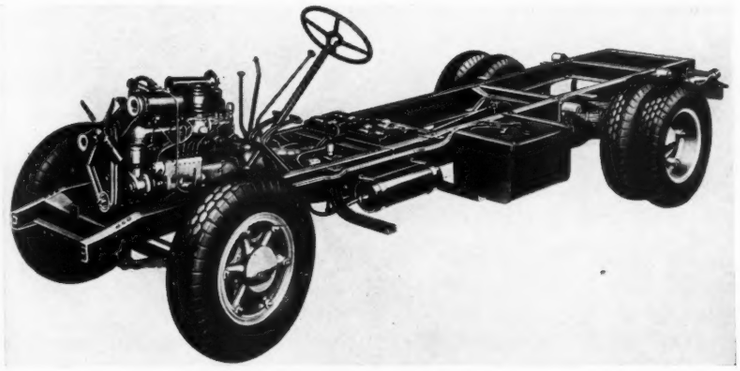
By flattening the leaf spring through a vertical movement of the hydraulically operated piston, the toggle action produced moves the wheel head of this independent grinding unit forward for the feed

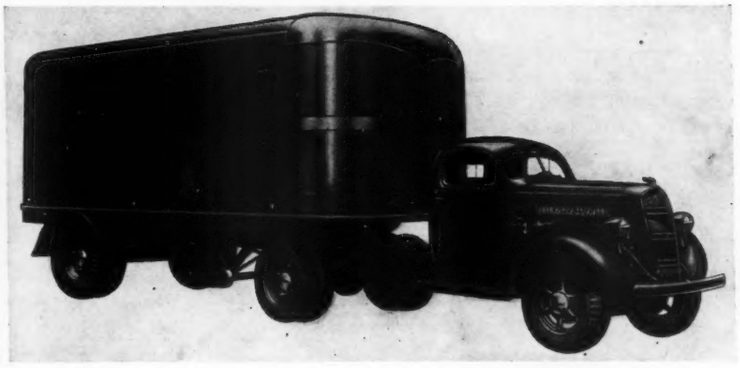


between the wheel head and the wheel-head slide with one end attached to the slide and the other to the head. The spring is under tension and in a bowed position when the wheel head is at the start of the feed.

By hydraulically flattening out the leaf spring through a vertical movement, as shown in the accompanying sketch, the spring ends spread and this moves the wheel head forward for the feed. Advantages are that there are no bearings to permit back-lash and the feed motion is relatively fast at the start but gradually slows down at the sizing position. As the wheel is moving into the final sizing position, the ratio of the vertical movement to the horizontal feeding movement is approximately 250:1, and the effect of errors in the stopping position of the vertical movement are therefore minimized.

The rate of grinding feed is controlled by a hydraulic metering valve through a dial on the panel shown in the illustration. Besides the slow grinding feed, the head has rapid traverse, grinding dwell or spark out, and rapid return to starting position, the complete cycle being started by one pushbutton. The dwell time is governed by an electric-clock-motor-controlled time-delay switch. The setting of a graduated dial, operated by a small hand wheel, determines the amount of stock removal, with a maximum of $\frac{1}{8}$ in. on the diameter.





New Diesel Truck

Studebaker enters the Diesel-powered truck field with this high-speed model for heavy haulage. Powered by a Hercules 3½ x 4½ in., six-cylinder engine, with torque rating of 174 ft.-lb. at 1,200 r.p.m., 260 cu. in. piston displacement. Differs from the company's standard gasoline-powered truck in that it has a two-speed, double-reduction rear axle, a five-speed transmission, a heavier steering gear, larger radiator core, viscometer on dash, vacuum booster brake system, and 24-volt heavy-duty electric equipment. Lockheed hydraulic brakes, 14 x 2 in. on front, and 16 x 3 in. on rear wheels. Chassis designed for 9, 12, and 15 ft. bodies.

RANDOM JOTTINGS ABOUT NEW DEVELOPMENTS

A novel striped effect is achieved on an electric range manufactured by Ennis & Williamson Co., Buenos Aires, Argentina, by polishing and buffing the stainless-steel metal surface. Panels of 23-gage Armco 18-8 stainless, No. 2B finish, are stamped to produce uniform ridges in the metal. The protruding ridges are polished to a lustrous No. 7 finish, while the indentations retain their original dull finish. The simple operation provides a marked contrast.

* *

Tires of 6 ft. 6 in. overall diameter and 2 ft. 3 in. width, said to be the world's largest, were recently completed at Fort Dunlop, Birmingham, England, for the new Armstrong Whitworth planes of Imperial Airways. Two of the tires can be used for an airplane weighing more than 22 tons. To permit proper molding of such a tire, an internal pressure of 250 lb. per sq. in. was required, giving a total pressure of approximately 390 tons that the mold had to withstand. A 10-ton ladle was required for pouring the steel necessary for the mold castings. The weight of air contained in each tire at 40 lb. per sq. in. is 10 lb. approximately.

* *

Railroads are modernizing with Monel. One line is installing window sill strips and wash basins of this alloy, while another is using it for lavatory equipment.

* *

To enable users of its stapling wire to dress up their products, the Acme Steel Co., Chicago, has taken the first step by dressing up its own product. It has recently announced a stapling wire available in a large variety of colors and in all standard sizes. The product, known as Colorstitch, has the same rust-resisting qualities as the company's galvanized stapling wire.

* *

Six new Pan-American Clipper ships are being equipped with exhaust manifolds and cabin heaters made of Inconel.

* *

Through a novel use of sound waves, Chevrolet is reported to have measured the combustion-chamber volume of its new engine. A whistle was screwed into the engine in place of a sparkplug and compressed air applied to it. Air of the same pressure was also applied to another whistle attached to the end of a variable-volume chamber. By varying the volume of the chamber until the pitch of the two whistles was the same, the unknown quantity was obtained.

SUBSTITUTION OF MATERIALS

Does Not Necessarily Constitute Invention

H. A. TOULMIN, JR.
Patent Attorney

The author outlines as a guide to designers the narrow field for achieving patentability or avoiding infringement by substituting one material for another in machine or product construction

FROM NUMEROUS patent suits it appears that many designers are under the impression that to substitute one material for another will entitle them to a patent. In the majority of cases it will not, although under certain fairly rare conditions a change of materials has been held to be patentable.

The test is whether the new design is the product of inventive skill, of the creative faculty, or merely the result of good manufacturing judgment, engineering knowledge or common mechanical skill. To be invention the creative faculty must have been exercised.

In applying this test to "inventions" involving a change of material, great care must be used, for the line is not always easy to draw. Thus, the courts have held that to make roller skate trucks of sheet metal instead of cast iron was not patentable, although the new design made the skates lighter, cheaper and stronger. The substitution called only for good judgment, not inventive skill.

Rules for Guidance

On the other hand the substitution of a rubber button for a metal button on garters was, the court decided, invention that deserved patent protection, for the change in material transformed a device which was destructive to hosiery and so was unsuccessful, into one which was highly successful in accomplishing its objective.

In contrast with this case is one which to the layman might readily seem a close parallel. It involved substituting a rubber spring for a metal spring in corsets. It probably made the corset more comfortable and more durable—but it was not invention.

The field for achieving patentability, or avoiding infringement, by substituting one material for another is so very narrow that most cases involving the question have been decided in the negative. The rule may be stated as follows:

The substitution of materials may constitute invention:

1—When it results in a new result not usually associated with the material.
2—When it involves a new type of construction.
3—When it enables new uses to be made of the device.
4—Above all, when it makes an existing device successful for the first time.

On the contrary, substitution of one material for another does not constitute invention:

1—When it merely makes the device more durable.
2—When it is merely the replacing of an inferior material with a superior one.
3—No matter how great the increase in the utility of the device, if the improvement is the result solely of good judgment in selecting a material whose characteristics are already known.

An examination of how these rules work out, when they are applied to specific cases decided by the courts, will probably make them more vivid and more easily applicable to the problems that designers encounter.

Some Specific Decisions

Cement is not commonly considered acid-resisting, yet one court decided, "invention was involved in providing a digester tank with a lining of cement, although it was old to line these tanks with acid-resisting material such as lead, and it was old to use cement lining for walls of open vessels for heating solutions. The patentee discovered that under the condition of closed vessels the sulphite layers at high temperature and pressure would not attack a cement lining. This new result was deemed sufficient to sustain the claim of the patent."

It was held to be patentable invention to make building blocks of cinders, cement and water instead of sand, cement and water. Inasmuch as the substitution of cinders for sand made the blocks sound-proof, damp-proof, fireproof and electrically non-conducting, the court found that they were a valuable contribution to the building art and therefore a patentable invention.

However, it was held that no invention was involved in making wall-board out of plaster of paris, cement, hair, wood, fabric, sawdust, excelsior, wood shavings, wool, straw and other similar substances instead of plaster base compositions of the prior art which utilized as the organic constituent, fiber board, sugar cane fiber, cork or other materials which are subject to expansion and contraction.

Increasing Effectiveness

In an electric make and break contact, tungsten was substituted for iridium platinum. It was regarded by the trade as cheaper and far superior to the old contact. The court held that it took more than uninventive substitution to make this change and that the invention was therefore patentable.

But it was decided by another court that to substitute in a heating device a radiator of copper for one of cast iron or other heavy metal, even though the copper radiator were more efficient, was not patentable. It was well known that copper is an efficient heat transmitter, and, since there was no change in the function or effectiveness of the combination, there was no invention.

On the other hand, the court held valid a patent for a water cooler using a coil made of a resilient metal instead of a non-resilient lead or block tin pipe of which the coils had formerly been made. The problem had been to find a coil material which would not be damaged by falling pieces of ice. The substituted material performs a new function and its adaptability for the purpose was not evident, as shown by the fact that those familiar with the art had been striving for 50 years to find a way to protect the coils.

The substitution of metal parts for

wood has many times been decided to be unpatentable, yet inventors are still frequently hitting upon the same idea. It is held to be merely the use of reasonably good judgment to substitute a more rigid or durable material.

It was old practice for silk stockings to be made of organzine in order to get a heavy stocking with a dull finish. A patent involving the twisting of yarn in a certain way in order to secure a sheer hose with a dull finish was declared invalid on the grounds that anyone skilled in the art would know how many twists to give the yarn in order to secure the desired result.

Inventive Faculty Shown

Certain woven wire screens had been made with a small wire running one way and a large one the other. In order to get the desirable result of having the two sizes of the same strength it was proposed to make the smaller wire of a harder metal. Again, it was what would naturally be done by any capable mechanic and so did not evidence the use of the inventive faculty.

An important basic patent was that covering the substitution of tungsten as a filament material in electric lamps in place of the carbon filament used for many years. The new material so greatly reduced the current consumption per candle power as to practically revolutionize the electric light industry. It was not an obvious substitution. In fact the lamp manufacturers had been searching for years for better filament materials.

In the same way, it was invention to substitute a known metal alloy in stated proportions for the ineffective materials formerly used as resistance elements. The substitute material made commercially practicable the manufacture of a large line of electrical power-using devices.

Advance in the Art

If the use of a substitute material results in a marked advance in the art it will usually be held to be patentable invention. Thus Claude, by substituting neon for the commoner gases such as nitrogen and carbon dioxide formerly used in the Moore tube, contributed greatly to the commercial utility of the light by virtue of the increased quantity and pressure possible only with neon.

Usually merely increasing the convenience, cost and so on of a device does not constitute invention. However, one inventor was able to uphold his patent on an ash receiver made of glass instead of the opaque material formerly used. The court said that the "apprehension of the labor-saving, convenient and neat device disclosed in the patent involved more than the work of a routine mind".

But on the other hand, another court held that in making non-discolorable safety glass there was no invention in substituting for a certain type of plastic strengthening layer, such as celluloid interposed between two layers of wind-shield glass, another kind of pyroxylin plastic previously used, where the advantage of the substitution is attributable to inherent physical attributes of the substitute itself.

A patentee sought to establish his right to a patent for a self-lubricating drier used in paper making machinery in the drying and bleaching of paper. The Patent Office had held that substituting a self-lubricating carbon or graphite packing ring for the old form of steel or brass ring was not invention. But the Court to which the case was taken felt that the substitution resulted in more efficient action, that saving resulted in the cost of paper machines so equipped and that explosions due to excessive internal steam pressure in the old type of device were eliminated. The patent was upheld on the ground that where the substitution of one known material for another actually involves a new mode of operation or construction, or evidences its superiority in more efficient action "it may amount to invention."

One inventor substituted an aluminum alloy arm for a cast iron arm in clicking machines used in manufacturing shoe uppers. The Court held that a new and useful result was obtained by this substitution, notwithstanding that the characteristics of the alloy were well known; that there was an increase in the efficiency and a decided saving in operation costs; and that therefore this substitution constituted a patentable invention.

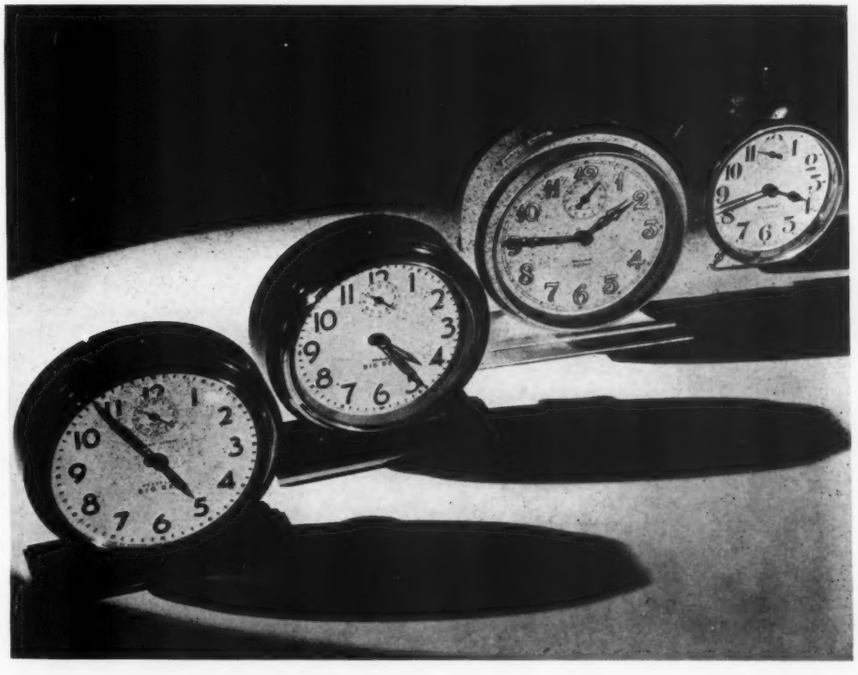
Preliminary Test

Another case involved the making of scale drums with a thin skeleton frame covered with a thin sheet of paper, instead of the heavier metals of the prior art. The old type scale was not reliable. Using the lighter materials made the scale sensitive to small weights, and resulted in accurate registering of the weights. The court found that this substitution of materials resulted in a scale which was a very ingenious contribution to the art and that the patent was therefore valid.

The designer who is faced with the question of whether a substitution of materials will result in invention, or avoid infringement, can well test it, at least preliminarily, by this statement of Mr. Justice Bradley of the Supreme Court of the United States, concerning the substitution of materials.

"The use of one material instead of another in constructing a known machine is in most cases so obviously a matter of mere mechanical judgment and not of invention, that it cannot be called an invention unless some new and useful result, an increase of efficiency, or a decided saving in the operation, is clearly attained."

Using one material for another when redesigning a product cannot be called an invention unless some new and useful result, an increase of efficiency, or a decided saving in the operation, is clearly attained



SPRING DESIGN CHARTS

for Cylindrical and Conical Springs

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THE ACCOMPANYING charts for selecting the diameters of spring wires and coils for given values of deflection characteristic are constructed on the stress-deflection formulas incorporating the Wahl factor. The curves are given for wire diameters corresponding to Washburn & Moen, W&M, gage for steel and Birmingham or Stubbs, B&S, for brass wires, using the following values of the modulus of elasticity in shear: 11,500,000 lb. per sq.in. for steel; 6,250,000 lb. per sq.in. for phosphor bronze and 5,500,000 lb. per sq.in. for brass. In the charts and equations:

t is the "factor of safety," its numerical value to be selected from Table I.

P_1 is the initial steady load, preloading, on the spring in lb.

P_2 is the maximum working load imposed on the spring in lb.

tP_2 is the breaking load in lb. exerted on spring.

D is the outside diameter of spring coils in inches.

d is the diameter of spring wire. Values given on the curves correspond to W&M or B&S standard wire gages.

F is the inches deflection of spring from the position of its loading under the load P_1 to the position of its maximum compression or extension under the load P_2.

n is the number of active coils.

m is the number of inactive coils.

Number of end or inactive coils m for compression springs are selected according to number of active coils. Thus with n less than 5, $m = 1.5$; with n ranging from 5 to 10, $m = 2$; with n equal to or greater than 10, $m = 2.5$. For extension springs with end attachments 3 coils at each end should be sufficient while a value of $m = 1 + \frac{3}{4} = 1\frac{3}{4}$ is a good value for conical springs.

By the use of the accompanying charts the designer can establish values of spring wire diameters and the number of active coils for the materials listed in Table I using values of safety factor t corresponding to the material selected. Although the curves were constructed specifically for cold drawn spring wire, Fig. 1; silico manganese steel, Fig. 2; and phosphor bronze wire, Fig. 3, the use of the proper factor of safety as tabulated makes them applicable to the other materials as indicated in the grouped tabulations. The detailed procedure will be illustrated by examples.

Example 1. A compression spring suitable for a 3 in. safety valve is to be designed, using standard 0.55 carbon steel as listed in column "d" in the table. For limited service of spring, that is, the number of deflections during the expected life of the spring well within the endurance limit of the material, but considering that failure might have serious consequences, select $t = 3.5$ as given in Table I. Values specified by the requirements of the design are: $D = 4\frac{1}{2}$ in., $F = \frac{7}{8}$ in., $P = 1{,}200$ lb., $P_2 = 1{,}600$ lb. Hence $tP_2 = 3.5 \times 1{,}600 = 5{,}600$ lb. Using the chart Fig. 2, from the point in the right hand scale designating $tP_2 = 5{,}600$ trace along the diagonal to the sloping line representing $D = 4\frac{1}{2}$. The next higher of the sloping lines on the left hand scale gives $d = \frac{3}{4}$ in. or the correct wire diameter.

The number of active coils n can be estimated from the chart in Fig. 4. For a cylindrical coil $R/R_1 = 1$. Also $R_1/d = (D - d)/2d = (4.5 - 0.75)/(2 \times 0.75) = 2.5$. Using the lower chart in Fig. 4, the ratio of minimum to maximum mean radii being one, from the point in the bottom scale designating $R_1/d = 2.5$, trace vertically to the sloping line marked by $R/R_1 = 1$. Then trace horizontally from this point to the right hand vertical scale, which indicates $A = 0.94$ for the value of the deflection characteristic. Then

$$n = \frac{10{,}000\ Fdk}{(P_2 - P_1)\ A} = \frac{10{,}000 \times \frac{7}{8} \times \frac{3}{4} \times 1}{(1600 - 1200) \times 0.94} = 17.5$$

Assume $m = 2.5$. Initial height or length of a compression spring in preloaded position is:

$$L = (n + m - 0.5)\ d + \frac{1.05\ P_2 - P_1}{P_2 - P_1} \times F$$

$$= (17.5 + 2.5 - 0.5)\ \tfrac{3}{4} + \frac{1.05 \times 1600 - 1200}{1600 - 1200} \times \tfrac{7}{8} = 15.68 \text{ in.}$$

This equation allows an added 5 per

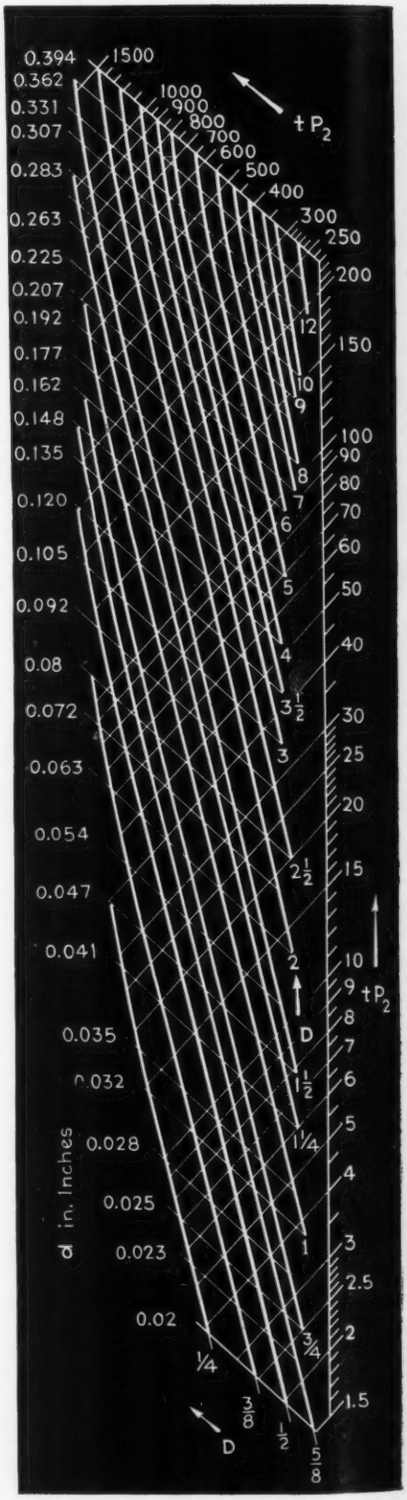


Fig. 1—Chart for calculating springs of 0.55 carbon steel cold-drawn wire

cent in maximum load before the spring coils clash.

Final height of spring when under maximum load P_2 is:

$L_2 = L_1 - F = 15.68 - 7/8 = 14.8$ in.

Free height of spring is:

$$L_0 = L_1 + \frac{P_1}{P_2 - P_1} \times F$$
$$= 15.68 + \frac{1200}{1600 - 1200} \times 7/8$$
$$= 18.30 \text{ in.}$$

Length of spring wire

$$l = 3.14\ (D - d)\ (n + m)$$
$$= 3.14 \times 3.75 \times 20 = 236 \text{ in.}$$

Example 2. An extension spring for a controlling hand lever is to be designed, using commercial cold drawn steel wire as listed in column "*b*" in Table I. A factor of safety of $t = 3$ is given in the table. Values specified are: $D = 1\frac{1}{2}$ in., $F = 1\frac{1}{2}$ in. $P = 10$ lb., $P_2 = 90$ lb. Therefore $tP_2 = 270$ lb.

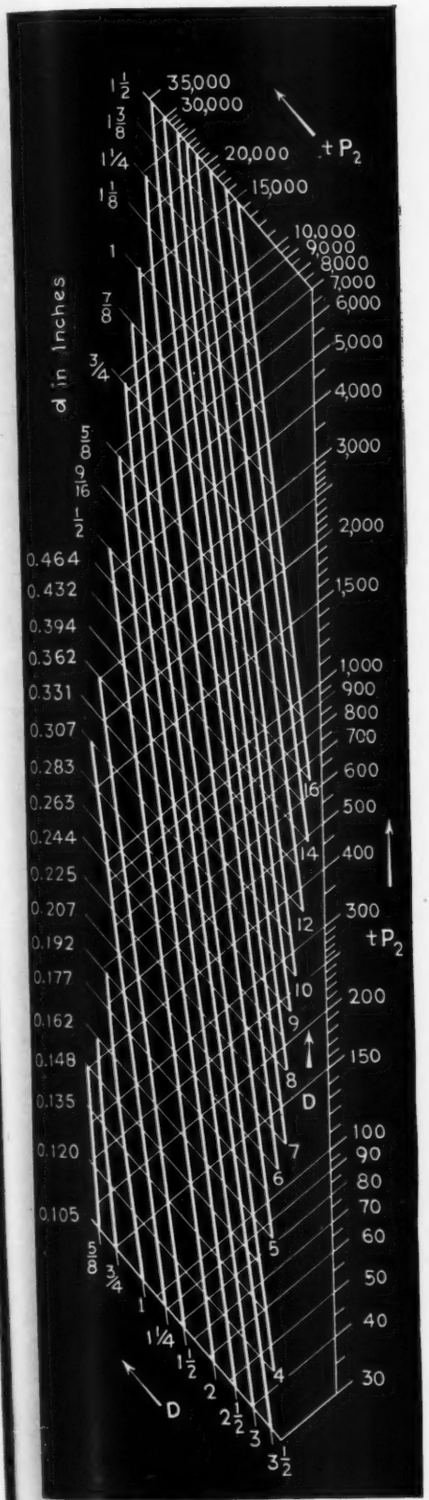


Fig. 2—Chart for calculating springs made of silico-manganese steel wire

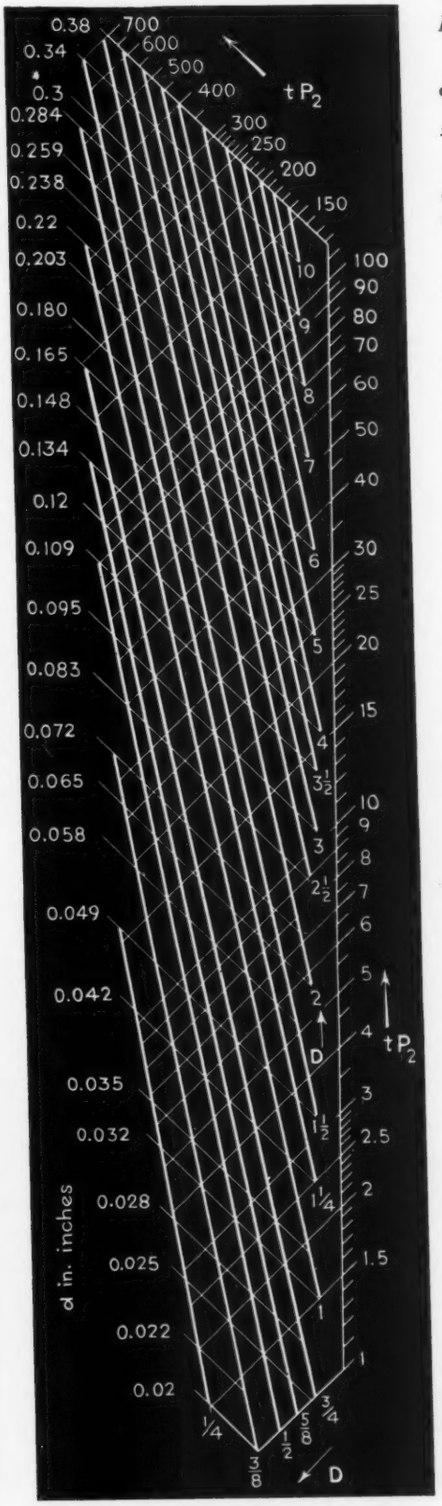


Fig. 3—Chart for calculating springs made of phosphor bronze wire

Using the chart in Fig. 1, with $tP_2 = 270$ and $D = 1\frac{1}{2}$ we obtain $d = 0.177$ in., the equivalent W&M gage number being 7. From the chart in Fig. 4, we obtain $A = 3$ for $R_1/d = (D - d)/2d = 3.7$ and, because it is a cylindrical coil, $R/R_1 = 1$. The number of active coils n is calculated as before and it is found that 11 are required.

Free overall height of spring fitted with "regular loops" and attachment for which a length equal to D is allowed, will be:

$$L_0 = (d + x)\ n + D$$

To calculate x the manufacturing clearance between adjacent coils,

$$x = 0.15\ d = 0.15 \times 0.177 = 0.026 \text{ in.}$$

This assumes 15 per cent of the wire diameter for the clearance between turns of the coil.

The free overall height will then be:

$$L_0 = (0.177 + 0.026)\ 11 + 1.5$$
$$= 3.73 \text{ in.}$$

Initial height of spring preloaded will be:

$$L_1 = L_0 + \frac{P_1}{P_2 - P_1} \times F$$
$$= 3.73 + \frac{10}{90 - 10} \times 1.5 = 3.92 \text{ in.}$$

Final height of spring under the load P_2 is

$$L_2 = L_1 + F = 3.92 + 1.5 = 5.42 \text{ in.}$$

Length l of spring wire is:

$$l = 3.14\ (D - d)\ n + 3.14\ D = 51 \text{ in.}$$

Example 3. A compression conical spring for a controlling hand lever is to be manufactured of standard cold drawn 0.55 carbon steel wire listed in column *a*, the table indicating a factor of safety of $t = 2.5$. Values specified are: the largest outside diameter of the active coil at the base is $D_1 = 2\frac{1}{2}$ in., the minimum inside diameter of the top coil is $D_0 = 1$ in. Further, $P_1 = 43$ lb., $P_2 = 84$ lb., working compression of spring is $F = 3/8$ in. By calculation, $tP_2 = 210$ lb. From the chart in Fig. 1 we obtain $d = 0.192$ in., corresponding to number 6 W&M gage.

The maximum or base mean radius of spring is

$$R_1 = 0.5\ (D_1 - d) = 1.154 \text{ in.}$$

The minimum or top mean radius is

$$R_0 = 0.5\ (D_0 + d) = 0.596 \text{ in.}$$

With ratio $R_1/d = 6$ and $R_0/R = 0.516 = R/R_1$ we obtain from the chart in Fig. 4 a value of $A = 6$. Thus

$$n = \frac{10{,}000 \times 3/8 \times 0.192 \times 1}{(84 - 43) \times 6}$$
$$= 2.9 \text{ or } 3$$

When establishing heights of conical

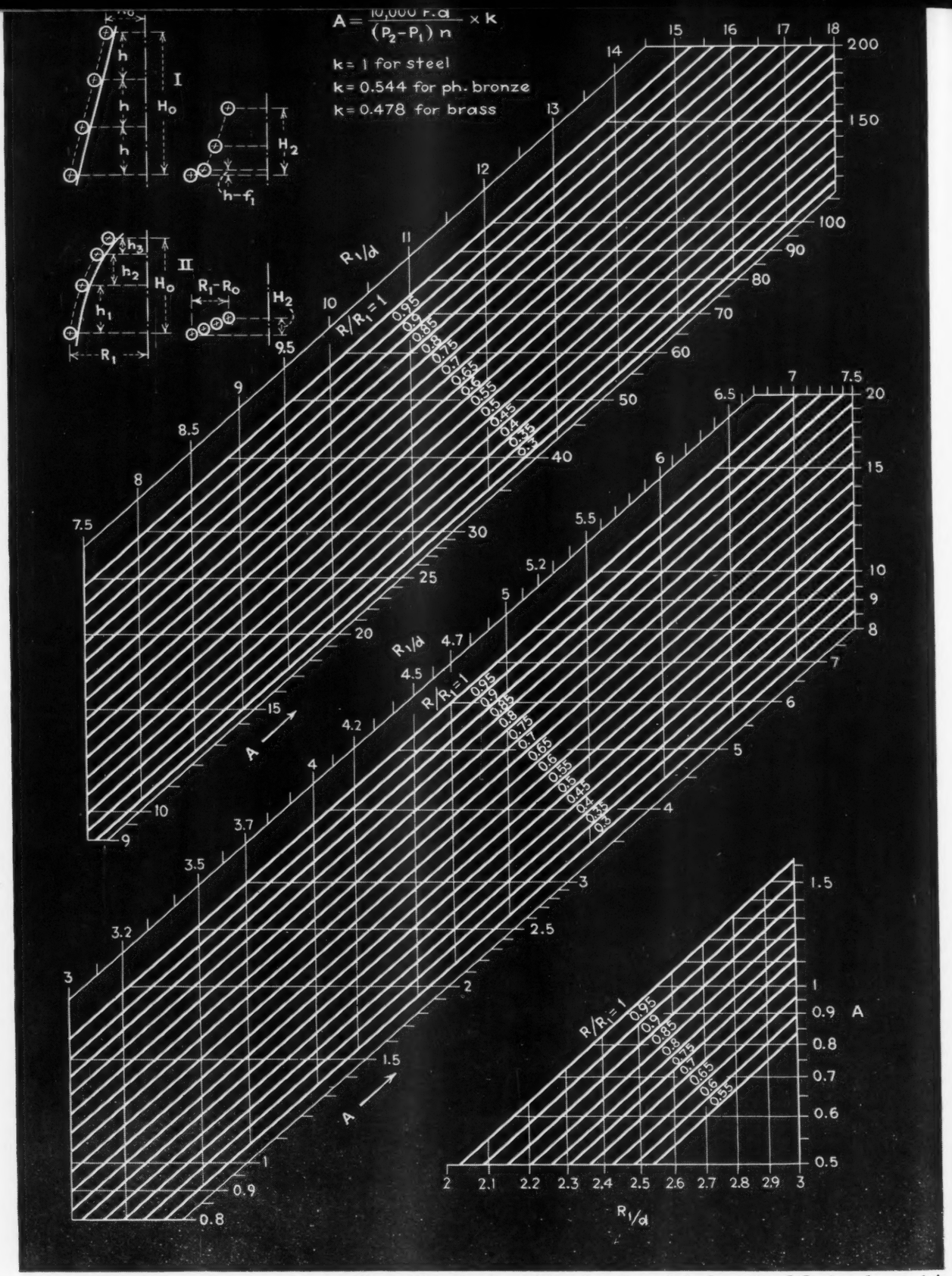


Fig. 4—Chart for determining the values of A, the spring deflection characteristic

springs, two methods of their manufacturing should be considered. The cheapest and most commonly used method is to wind the wire on a conically shaped arbor retaining equal distance, measured axially, between adjacent turns. Distance h between centers of coils should be selected on the basis of the maximum deflection f_1 under the load P_2 of the lowest active coil. See Illustration I in Fig. 4, which is self explanatory. Assume the base radius of the second coil to be R_2. Then

$$\frac{R_1}{R_2} = 1 - \frac{1}{n} + \frac{R_0}{R_1} \times \frac{1}{n} = 0.84.$$

$$\frac{R_1}{d} = 6 \text{ and } \frac{R_2}{R_1} = 0.84 = \frac{R}{R_1}$$

Knowing these values, we can obtain $A = 9.9$ from the chart in Fig. 4. Thus,

$$f_1 = \frac{AP_2}{10{,}000\ d} = 0.433 \text{ in.}$$

Assume $x = 1/32$ in. Then

$h = f_1 + \sqrt{(d + x)^2 (R_1 - R_0)^2 n^2} = 0.556$ in.

Free height of spring:

$L_0 = H_0 + (m - 0.5)\ d$
$hn + (m - 0.5)\ d = 1.98$ in.

Height of spring preloaded:

$$L_1 = L_0 - \frac{P_1}{P_2 - P_1} \times F = 1\frac{1}{2} \text{ in.}$$

Height of spring compressed by the force P_2 will be:

$L_2 = L_1 - F = 1.125$ in.

Length l of spring wire is

$l = [3.14\ (R_1 + R_0)\ (n + m)]1.02 = 26\frac{1}{2}$ in.

To design an economical spring, wound on a parabolically shaped arbor, see right hand Illustration II in Fig. 4. Assume as a basis the height H_2

$H_2 = n\sqrt{(d + x)^2 - R_1 - R_0)^2/n^2} = 0.369$ in.

TABLE I—*Factors of Structural Safety*

Nature of duty for which springs are required	FIG. 1		FIG. 2			FIG. 3	
	Cold drawn steel wires		Heat treated steels, quenched				
	Standard 0.55 carbon steel wires *a*	Commercial wires *b*	Standard silico-manganese steel *c*	Standard 0.55 carbon steel *d*	Commercial hot rolled bars *e*	Standard phosphor bronze wires *f*	Standard brass wires *g*
1. Limited service, failure not serious; springs under dead loads (springs of controlling hand levers, electric switches, door springs, etc.)	2.5	3	.....	2.5	3	2.5	3.7
2. Limited service, failure serious; (shock absorber, railway cars springs)	2.5	3.5	2.5	3	3.5	.....	.....
3. Limited service, failure serious; special light springs design (shock absorbers of gun carriages)	.....	.....	1.8	2.0	.....	.....	.....
4. Limited service, failure serious; permanency and accuracy of spring deflection are required (springs of safety valves, regulating devices, etc.)	3	.....	3	3.5	.....	3.5	5
5. Durable responsible work; live non-alternating load, no shocks (springs of steam engines regulators, metal and wood working machinery, dynamo brushes)	3.5	.....	3.5	4	.....	4	6
6. Durable responsible work; live non-alternating load, many millions of load applications, moderate shocks (springs of steam and gas engines valves)	4	.....	4	4.5	.....	4.5	6.5
7. Special heavy service springs; many millions of load applications, shocks, elevated temperatures not exceeding 300 deg. F. for carbon steel and 600 deg. F. for silico manganese steel (springs of explosion motors valves)	.....	.....	4.5	5	.....	.....	.....

Remarks: For steel springs working under corrosive conditions the tabular values of "l" should be increased at least 15 per cent.
Springs working in acids should be manufactured of phosphor bronze or brass.

Height of spring fully compressed:

$L_2 = H_2 + (m - 0.5)\ d = 0.609$ in.

Height of spring preloaded:

$L_1 = L_2 + F = 0.984$ in.

Free height of spring:

$$L_0 = L_2 + \frac{P_2}{P_2 - P_1} \times F = 1.38 \text{ in.}$$

The economical parabolical spring gives ½ in. decrease of height in preloading position. To describe a curve forming the side surface of the paraboloidal arbor, deflections of second and third coils under the load P_2 should be determined. Select distance between the top of first active coils and its base, namely $h_1 = 0.556$ in. as before.

The deflection of the second active coil can be estimated from the chart in Fig. 4 selecting:

Base radius $R_2 = R_1 - \frac{R_1 - R_0}{n} = 0.968$ in.

Top radius $R_3 = R_2 - \frac{R_1 - R_0}{n} = 0.782$

Ratio $\frac{R_3}{R_2} = 0.808$; $\frac{R_2}{d} = 0.504$

Then $A = 5.6$

$$f_2 = \frac{AP_2}{10{,}000\ d} = 0.245 \text{ in.}$$

Distance between the top of second coil and its base:

$$h_2 = f_2 + \frac{H_2}{n} = 0.368 \text{ in.}$$

To determine the deflection of third coil select:

$R_3 = 0.782$ in.

$R_4 = R_0 = 0.596$ in.

$\frac{R_0}{R_3} = 0.762$, and

$\frac{R_3}{d} = 4.08$. Then $A = 2.8$

$$f_3 = \frac{2.8 \times 84}{10{,}000 \times 0.192} = 0.123$$

$$h_3 = f_3 + \frac{H_2}{n} = 0.246 \text{ in.}$$

The three examples given above show the method of using these charts for the calculation of all types of extension and compression wound springs made of round wire. They give results well within allowable commercial error and will be found a great time saver not only in making calculation but also in checking calculated designs.

AMATEUR PHOTOGRAPHY

As an Aid in Engineering Work

ROBERT AVARD

Summarizing the numerous ways and means by which small cameras can be put to good use in recording visual data

IN MOST engineering offices, besides the data recorded by sketches and drawings made on the drafting board, copious notes are taken to record the construction and performance of each piece of equipment. Obscure points, however, are often missed by these records and can only be recalled from memory. The remembered data are often faulty and the record is incomplete and occasionally valueless as a result.

Our organization has used photography to record as much of such information as possible. This is especially true when we are studying competitive equipment. Since such equipment sells at list prices ranging from $50.00 to $600.00, our budget makes it inadvisable to buy more than a few machines. However, when we are able to borrow a machine or to see one in a friendly user's place of business, we arrange to have one engineer write it up and another photograph it in detail.

The write-up merely mentions the outstanding features and gives chief attention to performance. The photographs show not only the more important features but also include the minor ones. They illustrate the write-up and also supplement it, affording a graphic record of the machine.

Once the camera is set up, it is often possible to make a number of shots of various machine parts without changing the camera focus or the lights. One part is substituted for another as the exposure is made. In this way we complete data on the machine in the least possible time. Since the photographs have been taken with the purpose of telling about the machine, later reference will show any details that may be wanted.

Similarly, in order to have a complete record of designs, we photograph equipment at various stages of development. Drawings, of course, are also available, but we find that the photographs give more general information than the drawings. The drawings are the only source of dimensioned information but, for appearance designs, the photographs are invaluable. Our industrial designer has made it a practice to photograph all of his work as a method of recording.

It is often necessary for us to send data and information on tools and production methods to our foreign factory. Word descriptions and drawings are supplemented with 5 x 7 in. photographs to give complete information on the subject under discussion. To purchase these pictures from an outside concern would entail more expense than would be warranted. However, using our own equipment, we are able to produce the photographs at a fraction of the cost of sketches. We have sent as many as seventy prints in one shipment, when we were discussing the production of a new machine. The reaction from the men in the foreign factory was that the photographs were very valuable and aided materially in their understanding the discussion.

Equipment Used

The camera we have been using is a Leica with an f3.5 lens. This camera uses regular 35 mm. motion-picture film and is often referred to as a "candid" camera. A ground-glass copying attachment is used for close-up work. While the original cost of this equipment is higher than that of some of the bellows types of cameras, the cost of operation is extremely low—especially if one does his own processing. Any amateur camera will do most of the work, but best results will be obtained if a double-extension bellows and a ground glass are available for close-up work.

The procedure used in taking our photographs has been very simple. Two 200-watt lights in reflectors are used at approximately 45 deg. from the line between the subject and the camera. The distance of the individual lights from the subject is dependent upon the subject itself. The shadows are thus controlled to show the greatest possible detail. The 45-deg. angle is not rigidly adhered to, if other angles will serve better. For example, to photograph the interior of a tube it may be necessary to use only one light and to place it either as near to the camera as possible or at the far end of the tube. All exposures are determined with an exposure meter.

Our first photographs were taken as the result of a friendly argument between two engineers, both amateur photographers. The question was the relative merits of two cameras. Both men offered to take photographs of the same object. The final prints were to be submitted to the chief engineer for decision as to superiority. The argument ended in a dead heat but it produced, as a by-product, the suggestion that a file of photographs be made and maintained as an integral part of our engineering-department procedure.

However, our use of the camera has not been limited to the work already mentioned. We have found it a practical aid in many other respects.

For example, we recently purchased a special machine for production work. After the machine was delivered, it proved to be defective and had to be rebuilt. Payment to the original builder was held up and suit was brought by him for payment in full of the amount originally agreed upon, plus extras. About thirty photographs of this machine were made to show wherein it was defective. The pictures were taken with the idea of making the defects apparent to a jury of laymen. The advantage of this method, over blueprints and oral testimony, is obvious.

Assembly drawings for some of our older machines have been lost or destroyed since the machines were in production. To remedy this loss, we took one of each of these machines and made photographs of it in its entirety as well as of various subassemblies. The prints were made on 8 x 10 in. paper, and the part numbers were inserted by one of our draftsmen. The cost of this procedure was much less than that of making drawings to cover the same information. Since no dimensions were necessary, there was no need of showing the machines to exact scale.

We often have valuable documents that must be consulted frequently. To save wear and tear, we use the camera to make copies of these. The originals are then stored in a safe-deposit vault and the copies are used for reference. In this respect, it must be said, however, that it may be cheaper to use regular photostatic copies unless the originals are of such a nature that they cannot be sent to the photostat shop.

Another use of our camera is the making of photographs of hand-made samples with which to furnish suppliers the information that is required for preliminary quotations, as well as to suggest tool constructions to them. This method of transmitting the data has received favorable comment from the suppliers. Here, however, the use of photographs is limited to those items on which general information is wanted and on which outside dimensions only are furnished.

Other Uses

At trade shows and technical expositions, a small camera with a fast lens is of great value in recording information that is not available in the trade literature that is passed out. Candid shots of a booth in which machines with cutaway sections are displayed will preserve the information for future reference.

Even our chemist has found it practical to call on our amateur camera to aid him in his work. He desired a permanent record of some microscopic material but felt that the cost of obtaining the photographs from a commercial laboratory would entail more expense than was justified. We experimented using a 100-power microscope and our small camera with a piece of hair as a subject. The microscope was set visually so that the hair was in sharp focus. The camera lens, wide open and set at infinity, was held against the eye-piece of the microscope. Several negatives were exposed to determine the time of exposure required and to make minor corrections in focus. The final results, although not as good as might be obtained by equipment especially designed for the purpose, were entirely satisfactory.

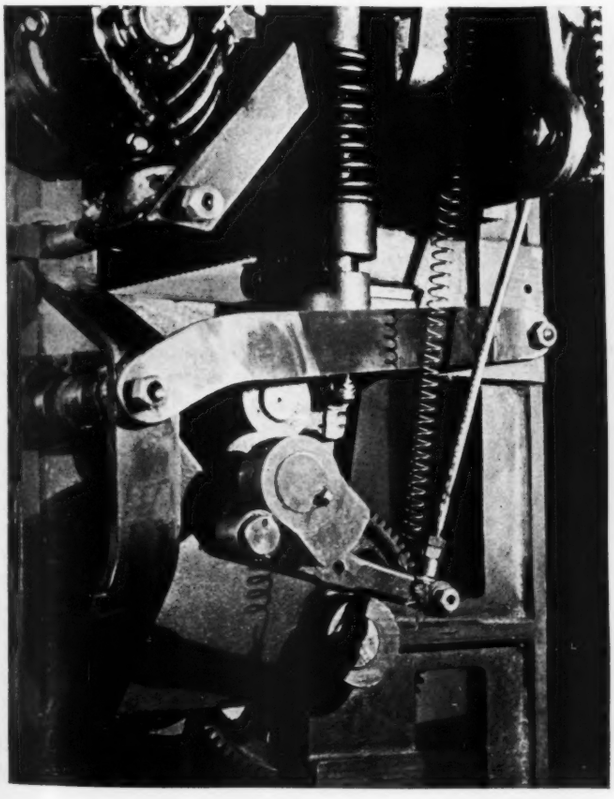
These few examples of the use that can be made of a good amateur camera are merely indicative. Any subject from a huge machine to a microscopic specimen can, after a little practice, be successfully photographed. It is really difficult to understand why more engineers do not take advantage of the opportunity.

After all, as a group there are probably as many amateur photographers among engineers as there are in any other profession. The majority of these, however, use their cameras only for recording personal events. When they go to the office, their cameras are left at home. Often their technical pictures are taken by some commercial photographer who may have little understanding of the work he is recording and therefore merely "shoots" in the general direction indicated by the engineer. Thus, because the non-technical professional's work must usually be carefully directed, more time is often taken to describe in detail what is wanted than is required to take the picture after the idea has been explained.

Frequently, too, a professional is not readily available at the opportune moment during the construction of a machine so that a picture can be taken to show some interesting feature of its design. As a result, many opportunities to snap certain worthwhile photographs, which oftentimes might later prove to be of considerable value, are foregone in order to avoid delay.

How much better it would be if the engineer were to use his own camera to get those "straight" (that is, not necessarily artistic) technical photographs that are related to his work. Since the engineer knows exactly what he wants to record, no time need be wasted in explanations and, even though his photographs do not have the artistic perfection of commercial shots, they will at least show all essential details. The important point is that his use of the camera makes it possible to obtain many valuable visual records which otherwise would not be made at all. The possibilities, we found, are almost unlimited.

(Left) Details of a cam for actuating a pressure bar and the spring-return arrangement employed are visually recorded by Mr. Avard's camera. (Right) Here, the author shows what his lens can do when called on to capture details of a cam used to cause lateral motion of a cutting knife



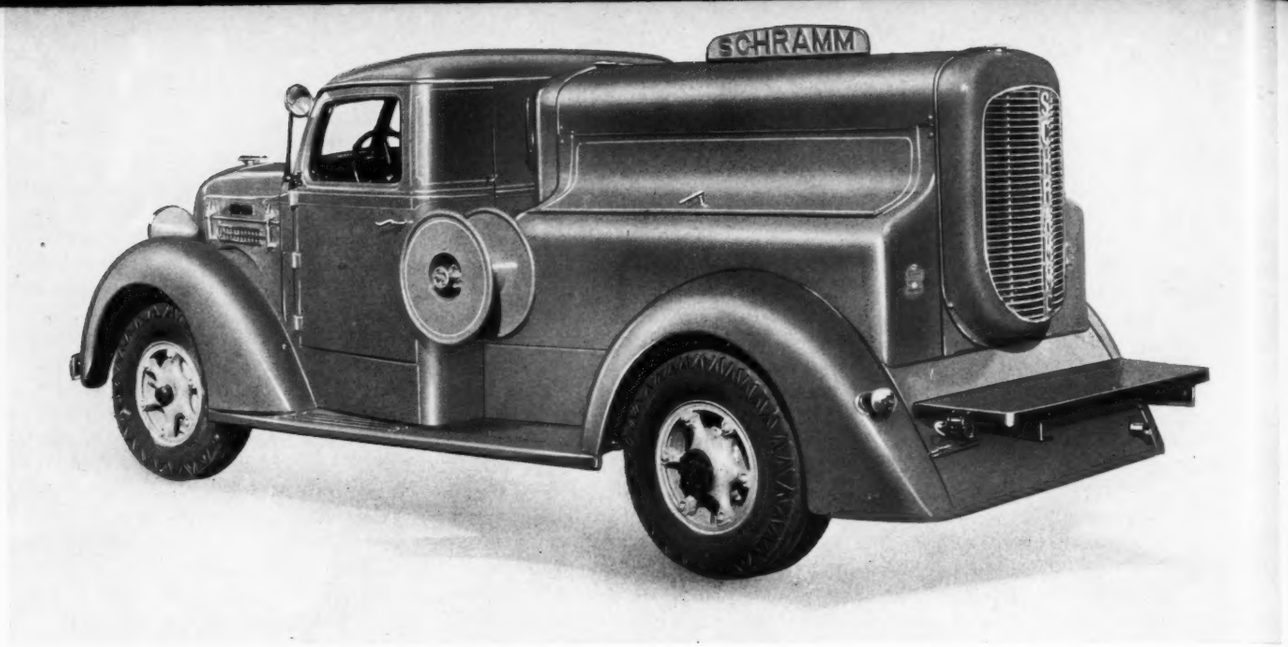


Fig. 1—One of the 105-cu.-ft. compressor units mounted in place of "pick-up" body on a ½-ton truck chassis

DOVETAILING DESIGN IDEAS

to Meet New Needs and Trends

That's what Schramm, Inc., did in designing its recently announced line of "Utility" air compressors, and here's how the various factors involved were treated in developing the final design to suit new requirements

IT WAS BACK during the early days of the Great Depression, when prosperity was still "just around the corner," that some of the keener observers in the organization of Schramm, Inc., of West Chester, Pa., began to notice something different about the way people were using air compressors.

In the building field, those contractors who were lucky enough to have a couple of jobs to work on were getting along with one compressor and moving it around from job to job—sometimes two and three times in a single day.

In the municipal utility field, something akin was afoot. As old compressors wore out, they were not replaced almost immediately as they were during the middle Twenties. Instead, in many instances, parts were stripped from the worn-out units and used to keep the better ones in as good condition as possible. And the better ones were hustled around from job to job at rates of speed that made the contractors' compressors appear practically stationary. The railroads, too, were following just about the same procedure in this respect.

To the Schramm observers, these tendencies were manifestations of a new need—a need for lighter, more compact compressors that would better meet the requirements of portabilty.

It was at about the same time that truck engine manufacturers brought out the newer, peppier industrial engines, intended for general use but particularly adapted to engine-generator sets, since they did their best work at speeds up around 1,200 r.p.m. or higher.

One day, while a generator set driven by such an engine was being tested at

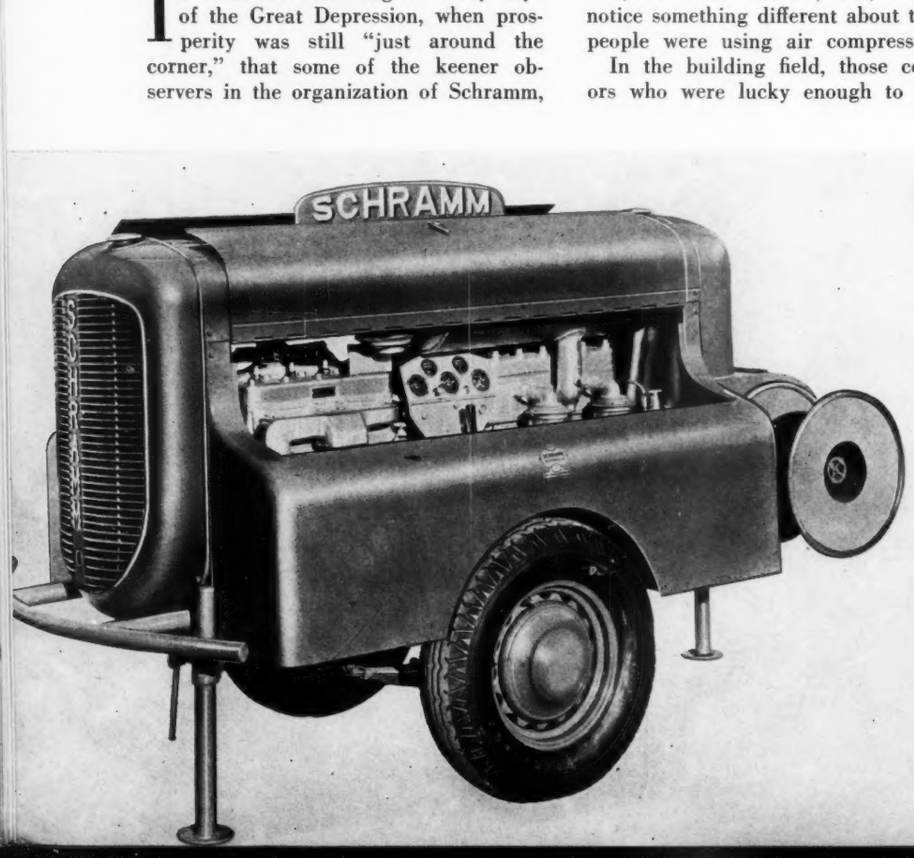


Fig. 2—Two-wheel trailer mounting of 105-cu.-ft. compressor unit, with side panels raised to show interior

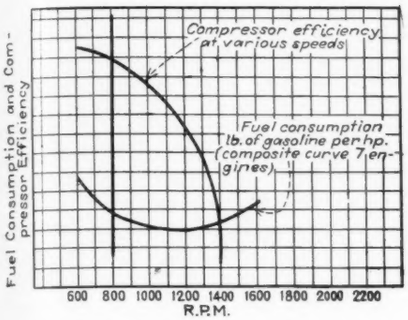

Compressor efficiency at various speeds
Fuel consumption lb. of gasoline per hp. (composite curve 7 engines)
Fuel Consumption and Compressor Efficiency
600 800 1000 1200 1400 1600 1800 2000 2200
R.P.M.

Fig. 3—Without mechanical inlet values, compressors drop off in efficiency at speeds above 800 r.p.m.

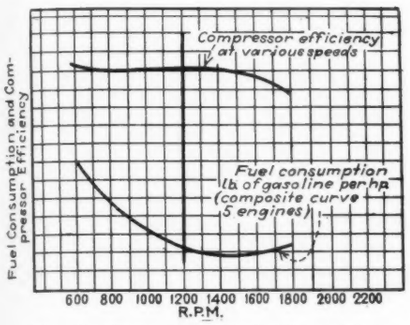

Compressor efficiency at various speeds
Fuel consumption lb. of gasoline per hp. (composite curve 5 engines)
Fuel Consumption and Compressor Efficiency
600 800 1000 1200 1400 1600 1800 2000 2200
R.P.M.

Fig. 4—With mechanical inlet valves compressors maintain relatively high efficiency at higher speeds, permitting operation at 1,200 r.p.m.

the Schramm plant, the plant manager turned to A. N. Gustafson, the chief engineer, who was standing nearby.

"Gus," he asked, "why can't we use one of those new babies to drive an air compressor?"

The engineer looked at the new engine. Compared to the rather ponderous, slower-speed industrial engines previously used, it was a mighty neat job. But it ran too fast to drive the current-model compressors, for which the accepted speed was about 800 r.p.m. Still, after several seconds reflection, Mr. Gustafson decided to give further study to the idea. After months spent in reviewing the various factors, he dropped over to the manager's office.

"Maybe we can use an engine like that to drive a compressor," he replied to the manager's question, and added, "but we'll have to build a faster-operating compressor first."

The reply was founded on the design thinking which, in the automotive and aircraft industries, had led to the trend toward higher speeds with smaller, lighter parts and more compact powerplants—the same trend that had produced the industrial engine under discussion.

Thus, on the one hand there was a need for a lighter, more compact driven machine; on the other, a trend toward faster (and, as a result, lighter, more compact) prime movers. From the design point of view, the two ideas might well be looked upon as counterparts. Dovetailing them produced the first of what, after further development, has become the "Utility" line of compressor units announced by Schramm earlier this year. From Figs. 1 and 2 a general impression of their compact, modern design can be obtained.

To step up the speed at which compressors operate, so that a smaller, lighter unit will do the same work as a slower, larger one, might at first thought seem to be a relatively simple matter. However, compressors for the most part use automatic intake valves, and Fig. 3 shows what happens to efficiency when the speed of such compressors is increased. The valve, depending upon suction for its operation, does not open soon enough for the cylinder to get a proper charge of air.

By using cam-operated intake valves in its new line, Schramm avoids this condition. As shown in Fig. 4, the cylinders get a sufficient charge of air at higher speeds and the compressors can therefore be operated at speeds very close to the minimum fuel consumption point of the modern industrial engines. Since the pistons operate oftener, smaller ones can be used. The size of bore and the weight of reciprocating parts can be reduced, and the entire compressor made correspondingly smaller and lighter. In the different sizes manufactured, Schramm estimates that a reduction in weight of from 28 to 48 per cent is realized from the increased speed.

Having decided to use mechanical intake valves, the designers next selected a design of block very similar to that generally employed in automotive practice. As can be seen in Fig. 5, however, there is only one valve port in the block for each cylinder, located on the same transverse centerline as the cylinder.

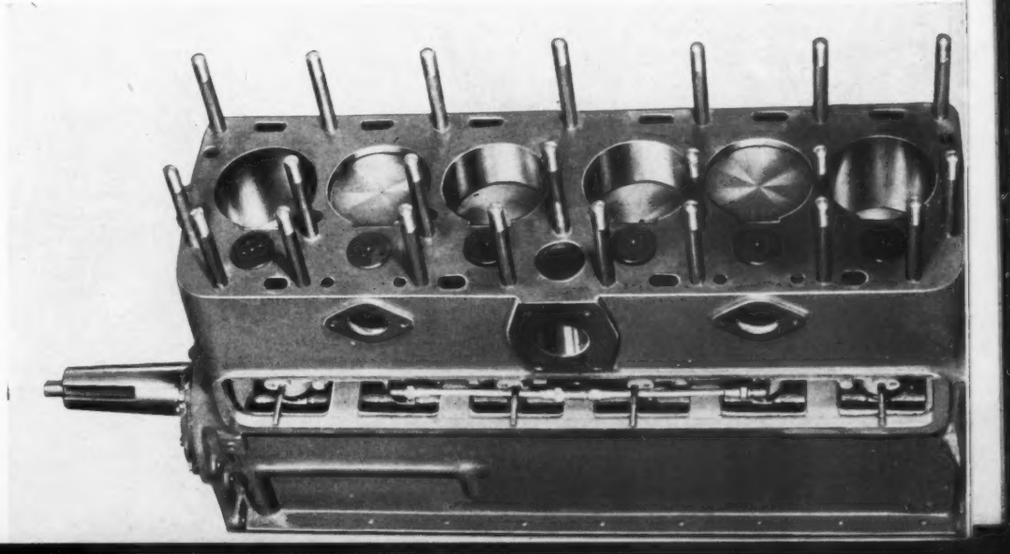
With this arrangement, it is possible to incorporate a large-diameter discharge valve in the cylinder head, as shown in Fig. 6. The fact that the diameter of this valve can be made almost as large as that of the cylinder bore makes it possible to obtain efficient discharge with only a small lift of the valve disk, as is illustrated in Fig. 7. The small lift minimizes clatter and wear.

Up to this point, the job of the designers was a relatively straightforward matter, consisting mainly of selecting what they considered the best features from both the automotive and the compressor field and incorporating them in the new unit. However, at this stage in the development the problem of providing a suitable means of unloading the compressor arose. With automatic intake valves, this can usually be accomplished without much difficulty, since the valves are commonly located in the head and therefore are in a convenient position for the provision of some suitable device which will hold them open.

With cam-operated intake valves located in the block, a simple method of holding them open was not so easy to devise. After several arrangements had been tried and found unsatisfactory, the design illustrated in Fig. 8 was hit upon. As can be seen, the valve push rods are made in two halves and ride in an unloader cylinder bracket.

When the air pressure in the receiver tank reaches the desired pressure, a pilot valve opens and allows air from the tank to enter the unloader cylinder bracket. This separates the two halves of the push rods and the valves are forced upward against machined bosses in the cylinder head. There they are held, in open position, while the lower half of the push rod rides up and down on the cam against the air cushion. At the same time, air from the pilot valve operates a small cylinder and plunger connected to the carburetor butterfly valve, slowing the engine down.

Fig. 5—Compressor block, showing location of inlet valves and general construction similar to automotive engine



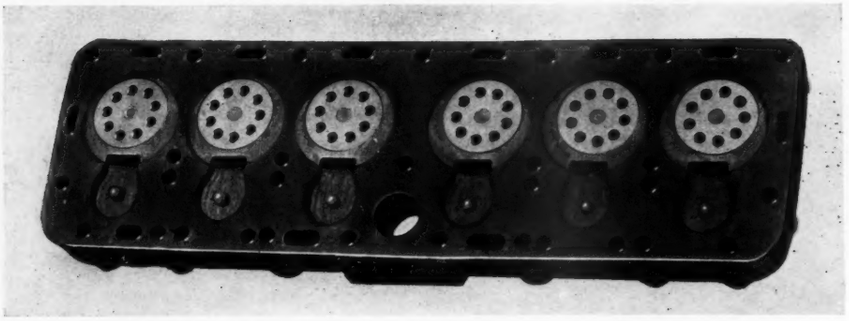


Fig. 6—Details of cylinder head show how use of mechanical intake valves in block leaves room for large-diameter exhaust valves in head

When the pilot valve returns to load position, upon decrease of pressure in the tank, the air cushion in the unloader cylinder bracket is allowed to escape and the two halves of the push rod then move as a unit in the same way as a conventional push rod.

With the unloading problem solved, the design of the "Utility" compressors was blocked out in general but there remained the design of cooling system, reciprocating parts, bearings, and last, but not least, the inclosure.

Water was selected as the cooling medium and jackets were arranged to surround every cylinder and valve. One of the reasons for selecting water was the fact that during cold weather the medium could be warmed up first by running the engine with the compressor clutch disengaged. The warm water circulating through the compressor block thins the lubricant around the pistons and valves, so that excessive wear does not occur when the compressor is first put into action.

Pistons are of grey cast iron and, together with connecting rods and wrist pins, follow the designs which, as Schramm puts it, "have been proved by hundreds of thousands of miles' service in truck and bus engines." Here, the designers were able to "borrow" the experience acquired by the designers in another field and they could therefore be sure in advance that the reciprocating parts would stand up at the faster speeds to which they were to be subjected. It should, however, be brought out that, although piston speeds are faster, the smaller size of the reciprocating parts results in lighter weight and for that reason the inertia and bearing strains are actually less than on the company's previous compressors.

Interchangeable bearings, also similar to automotive designs, are used for both connecting rods and crankshaft. To assure rigidity and long life, main bearings are provided between each cylinder as well as at the ends of the crankshaft.

When they came to the matter of providing inclosures for the compressors in the line, such as those in Figs. 1 and 2, which are "deluxe" models, the designers considered appearance-styling as the prime factor. They believed they had designed a modern compressor and they wanted it to look modern, on the theory that no one would recognize a modern auto chassis if it were hidden under a body designed five years ago.

With this in mind, they sketched up various designs for the radiator and inclosure. The designs were turned over to the shop and models made of wood, papier mache, and various odds and ends were turned out. Then, meetings were called with the executives of the various interested departments and the appearances of the different models were discussed in detail. A vote was taken and the winning design, instead of being accepted as final, was then subjected to critical scrutiny.

Minor points here and there were touched up, and further meetings were called to view the model. At the later meetings, salesmen from the field were brought in to present their views, and the design was not okayed for production until all concerned felt sure that it represented the best that could be done.

Another glance at the appearance of the units in Figs. 1 and 2 should convince anyone that the pains taken by the designers were not in vain.

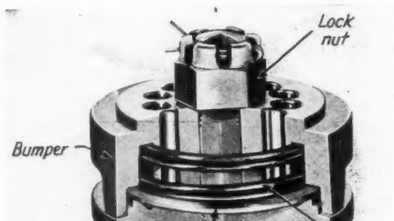


Fig. 7—Close-up of exhaust valve. Large diameter makes efficient operation possible with only a small lift of the valve disk, minimizing clatter and wear

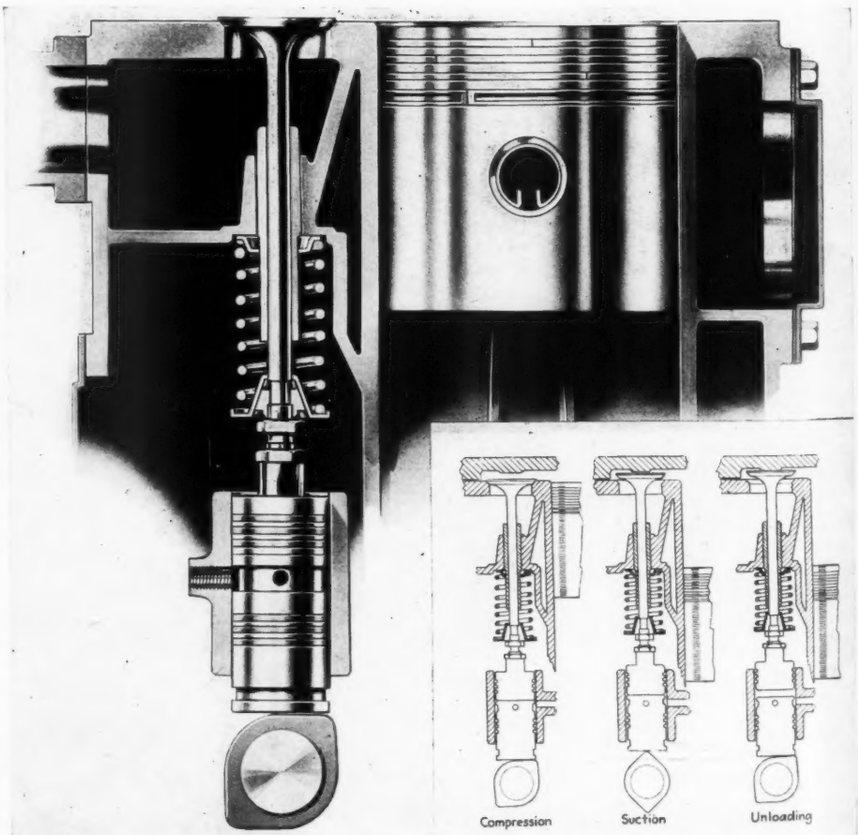


Fig. 8—Unloading action is obtained by allowing compressor air to separate two halves of valve push rod, holding valve open against machined boss in head

VISCOSITY

Analysis and Significance of Common Units

W. S. OWEN
Webb Institute of Naval Architecture

Development of various units of viscosity and correlation of English and metric measurement systems with conversion factors

PRELIMINARY to a discussion of viscosity it is important that the various units of force, mass and motion that are used in engineering and applied physics be clearly understood, because these units are fundamental not only in the measurement of viscosity but are also highly significant in calculations concerning hydraulic flow.

The word "pound" often causes confusion because while generally meaning a unit of "weight" or force, yet may be used to define a unit of "mass." This same dual meaning applies to the word "gram." The mental conceptions of weight and mass are not altogether unrelated, but the units themselves are decidedly far apart numerically. A good way to avoid confusion would be always to use pound or gram in association with either weight or mass, depending on whichever is meant, thus: "lb.—wt." or "lb.—mass"; or "gm.—wt." or "gm.—mass". The word "slug" has been coined to designate the unit "1 pound-mass."

Weight is the force exerted on an object by the gravitational attraction of the earth. This attraction or weight varies slightly from place to place, depending on the latitude of the locality and also on the distance either above or below sea level.

Although the weight of an object may vary, its "mass" does not. By "mass" is meant the quantity of matter contained in the object irrespective of its weight, its kind of material or the substance of which it is composed. If two bodies weigh the same in the same locality, it is correct to say their masses are equal.

According to Newton's Laws of motion if a force acts on a body of a given mass which is perfectly free to move in the direction of the force, then a certain acceleration will be produced in the motion of the body: also the amount of this acceleration will be proportional to the force acting. This may be expressed in any system of units as:

$$F = maK \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where F = number of units of force,
m = number of units of mass in the body,
a = the number of units of acceleration produced, and
K = a suitable constant depending on the units chosen.

In the C. G. S. system the unit of mass is that which is contained in 1 cubic centimeter of fresh water and is called 1 gram and the unit of acceleration is 1 cm./sec.^{2} With K taken as unity, the magnitude of the force that satisfies Equation (1) for one unit of mass and one unit of acceleration is taken as a unit of force and is called 1 dyne.

If a force of 980.9 dynes had been acting on a body of 1 gram-mass an acceleration of 980.9 cm./sec.^{2} would have been produced. But this is the same acceleration that would be produced on the 1 gram-mass by its weight in the latitude of Paris at sea level. Hence its force is also used as a unit of force and is called the 1 gram-weight. The acceleration of any object produced by its own weight is known as the gravity acceleration: and if measured in units of cm./sec.^{2} this acceleration is 978.1 at the equator, 980 at Washington, D. C., and 981.2 at London.

In the English system, the unit of mass selected is the mass contained in a certain body called the "1 pound-mass," or "1 slug," and this equals 453.59 gram-mass; the unit of acceleration is 1 ft./sec.^{2}, and again making K equal to unity, the force that satisfies Equation (1) is sometimes used as a unit of force and is called "1 poundal." A force of 32.15 "poundals" would produce on the 1 pound-mass an acceleration of 32.15 ft./sec.^{2}, which is the same acceleration as that produced by the weight of the object in Washington, D. C. This force is widely used as the unit of force and is called the "1 pound-weight." The mass of any object can always be expressed in terms of the units of weight and of gravity acceleration.

$$\text{Mass of given object} = \frac{w}{g} \quad \ldots\ldots (2)$$

The relationship between weight and mass in the latitude of New York is:

1 gram-weight = 1 gram-mass × 980 cm./sec.^{2} = 980 dynes

1 pound-weight = 1 pound-mass × 32.16 ft./sec.^{2} = 32.16 poundals

Irrespective of locality, 1 pound-mass, or 1 slug equals 453.59 grams-mass. In the same locality 1 gram-weight = 0.0022046 pounds-weight, or 1 kilogram-weight = 2.2046 lbs.-wt.

The unit of work or energy in the English system is the "foot-pound"; i.e., the work done by a force of 1 pound weight moving through a distance of 1 foot. Sometimes the unit of work is taken as the "foot-poundal," which is the force of "1 poundal" moving through 1 foot; but this latter unit equals 1/32.16 of 1 ft.-lb. In the metric system, the unit of work that is sometimes used is called the "erg", which is the work done by a force of 1 dyne moving through 1 centimeter.

When the various units described are clearly understood it should not be difficult to translate units which are used to measure viscosity into fundamental terms of mass, length and time. Translations and expressions of this kind are of great help in checking, for dimensional homogeneity or equality, the formulas and equations used in fluid mechanics.

Viscosity is that property which enables portions of liquid or fluid to offer resistance to the sliding motion of other continuous portions. This resistance in most liquids increases at first very

TABLE 1

Viscosity Unit Relations

Conversion from poises:

One poise or dyne sec./cm.^{2} =	
1.02×10^{-3}	kg. wt. sec./m.^{2}
2.09×10^{-6}	lb. wt. sec./ft.^{2}
1.45×10^{-5}	lb. wt. sec./in.^{2}
2.42×10^{-7}	lb. wt. min./in.^{2}

Conversion into poises:

One kg. wt. sec./m.^{2} =	98 poises
One lb. wt. sec./ft.^{2} =	479 poises
One lb. wt. sec./in.^{2} =	69,000 poises
One lb. wt. min./in.^{2} =	4,140,000 poises

TABLE II. Viscosity Conversion Formulas

t = Efflux time in seconds of apparatus

Viscosimeter	Kinematic Viscosity	
	Metric Units Sq. Cm./Sec.	English Units Sq. Ft./Sec.
Saybolt Universal	$0.0022\,t-(1.8/t)$	$0.00000237\,t-(0.00194/t)$
Engler*	$0.00147\,t-(3.74/t)$	$0.00000158\,t-(0.00403/t)$
Redwood	$0.0026\,t-(1.72/t)$	$0.00000280\,t-(0.00185/t)$

* *t for Engler=51.3×Engler Degrees.*

TABLE III. Viscosity Numbers for Crankcase Oils

S. A. E. Viscosity Number	Viscosity Range, Saybolt Universal			
	Seconds at 130 deg. F.		Seconds at 210 deg. F.	
	Min.	Max.	Min.	Max.
10	90 to less than 120		...	...
20	120 " " " 185		...	...
30	185 " " " 255		...	...
40	255	...	... to less than 75	
50	...	...	75 " " " 105	
60	...	...	105 " " " 125	
70	...	...	125 " " " 150	

slowly and then much more rapidly with the pressure between the sliding portions; the effect of pressure changes on viscosity at ordinary pressures is so small that it is usually neglected. The amount of resistance also depends upon the speed at which the sliding takes place. With an increase in temperature the viscosity of a liquid decreases, the rate of decrease is not the same for different liquids and is a characteristic of each liquid.

A quantity of liquid when considered to be made up of an infinite number of very thin layers or "laminas," having motion such that each lamina moves at its own speed in the direction of its length, yet virtually intact throughout, is said to be in "laminar flow."

The property of viscosity is exhibited in a liquid in laminar flow when the speed of each lamina is uniformly faster than the speed of the adjoining lamina on the other side, so that for any two adjacent laminas one is relatively at rest and the other one is sliding past at a uniform velocity.

Because of viscosity the force acting on the moving lamina causing the motion described, without acceleration, is exactly balanced by an equal and opposite resisting force offered by the relatively stationary lamina. These two forces constitute a shearing action, and the intensity of the resulting "shearing stress" induced in the liquid along the surface between the two laminas is equal to either one of the forces divided by the areas of the surface in contact.

In like manner, throughout the liquid there is a viscous force operating over the entire surface between any two adjacent laminas, and the intensity of the "shearing stress" in any such surface is directly proportional to the viscous resistance induced, and this in turn is directly proportional to the relative velocity of the laminas on opposite sides of that surface.

If Fig. 1 shows in cross section any small volume element of a fluid in laminar flow, that is, undergoing a shearing deformation without acceleration, and Δv represents the increment of uniform velocity between any two laminas of the liquid which are a small distance, Δy, apart; then the expression $\Delta v/\Delta y$ gives a measure of the rate of change in velocity between the two laminas in relation to their distance apart, and this is known as the "velocity gradient" or "rate of shear" between those two laminas. By selecting two laminas, each as close as possible to a given surface but on opposite sides of it, the "limiting value" of $\Delta v/\Delta y$ is represented by the expression dv/dy, which is known as the velocity gradient at that surface, and is therefore a measure of the relative velocity between adjacent layers.

Thus the viscosity is seen to be related to the shearing stress and to the velocity gradient at any internal surface of the moving liquid, and this relationship, stated by Sir Isaac Newton, is as follows:

Shearing stress in any surface of the liquid = $\mu \times$ velocity gradient at that surface.

Numerical value of constant represented by the Greek letter μ in this equation is called the "coefficient of absolute viscosity."

In the C.G.S. system the coefficient of absolute viscosity of a liquid can be expressed in dynes per square centimeter divided by centimeters per second per centimeter, which is the result of dividing "shearing stress" by "velocity gradient." Thus the "dimensions" of the coefficient of absolute viscosity are: dynes × seconds ÷ centimeters squared. In the C.G.S. system, the unit of absolute viscosity is called a "poise," from the name of the physicist and experimenter "Poiseuille;" this unit is the viscosity of a fluid requiring a shearing stress of one dyne per square centimeter to maintain a rate of shear equal to one centimeter per second per centimeter of lamina thickness, thus:

$$1 \text{ poise} = \frac{1 \text{ dyne} \times \text{second}}{\text{cm.}^2}$$

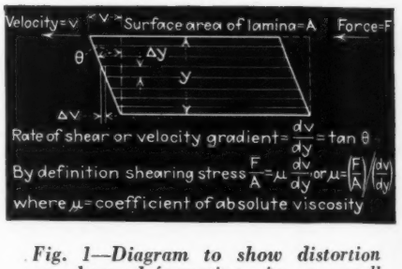

Velocity=V
Surface area of lamina=A
Force=F
θ
Δy
y
ΔV
Rate of shear or velocity gradient = dv/dy = tan θ
By definition shearing stress F/A = μ dv/dy or μ = (F/A)/(dv/dy)
where μ = coefficient of absolute viscosity

Fig. 1—Diagram to show distortion or shear deformation in a small volume of liquid in laminar flow

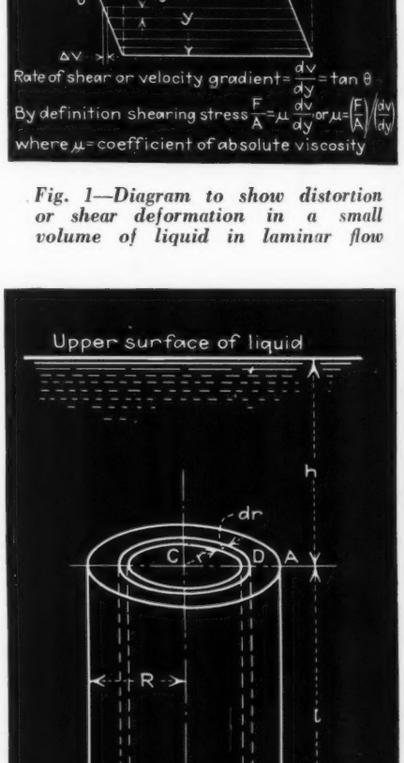
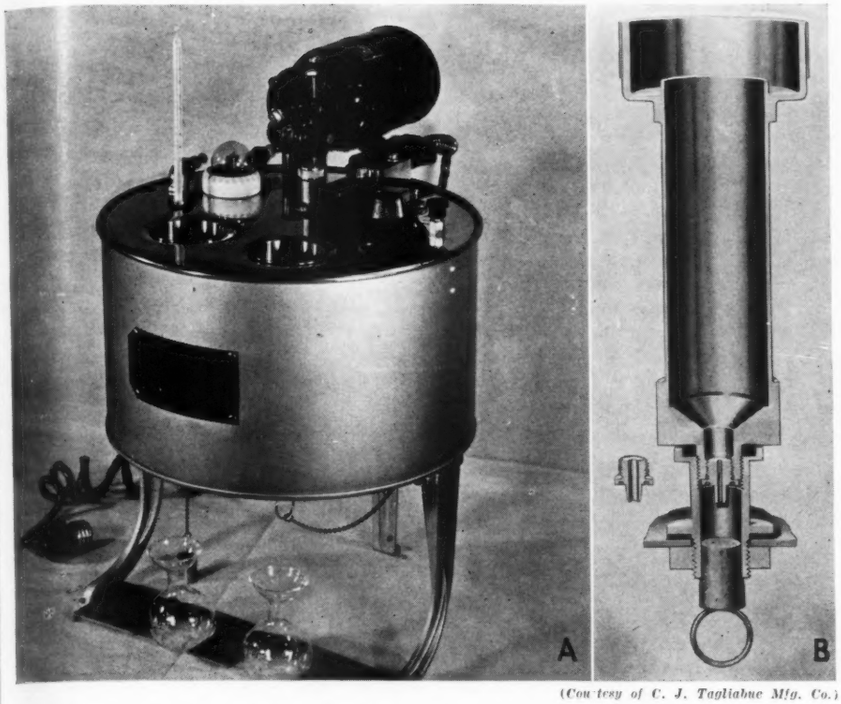


Fig. 2—Liquid in vertical tube flowing downward in laminar flow. Laminas are considered as series of concentric shells



(Courtesy of C. J. Tagliabue Mfg. Co.)

Fig. 3—(a) Saybolt Viscosimeter (b) cross section of tube and outlet orifice used in Saybolt Viscosimeter

A "centipoise" is one-hundredth of a poise; or 0.01 poise.

A centipoise can be converted into English units, where the unit of force is the 1 pound-weight (avoirdupois), and the unit of length is the foot, as follows:

1 centipoise $= 2.089 \times 10^{-5}$ lbs. wt. $\times$ sec./ft.^{2}

Conversion factors are shown in Table I for other commonly used absolute viscosity units.

In addition to the coefficient of absolute viscosity, there is the "kinematic viscosity" of the liquid, which is widely used and which measures a slightly different aspect of viscosity. The C.G.S. unit of kinematic viscosity is the "stoke," in honor of Sir George Stokes who contributed much to the theory of viscous flow.

$$1 \text{ stoke} = \frac{1 \text{ poise}}{\rho}$$ in which the mass density ρ is the weight of a cubic unit of the liquid w divided by g the gravity acceleration.

Kinematic Viscosity of a liquid in any system of measurement

$$= \mu/\rho \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$= \mu/(w/g) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$= \mu/(cs/g) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

in which c is the weight of a cubic unit of fresh water, and
s is the specific gravity of the liquid.

In the metric system the "dimensions" of kinematic viscosity are seen to be:

$$\frac{\dfrac{\text{dynes} \times \text{sec.}}{\text{cm.}^2}}{\dfrac{\text{gm.-wt. per cm.}^3}{\text{cm./sec.}^2} \times s} \simeq \frac{\dfrac{\text{dynes} \times \text{sec.}}{\text{cm.}^2}}{\dfrac{\text{dynes}}{\text{cm.}^3} \times \dfrac{\text{sec.}^2}{\text{cm.}}}$$

$$\simeq \frac{\text{cm.}^2}{\text{sec.}} \text{ or "velocity"} \times \text{"distance,"}$$

since s is "dimensionless."

The sign $\simeq$ is here used to denote dimensional equivalence.

Similarly, in the English system, feet^2/sec. are the "dimensions" of kinematic viscosity.

An idea of the physical meaning of "kinematic viscosity" can be gained from the following considerations:

Suppose a liquid, whose coefficient of absolute viscosity $= \mu'$, be subjected along an inner surface to a velocity of gradient of unity, that is, at the rate of 1 unit of velocity per 1 unit distance between the relatively moving and stationary laminas. Let F represent the viscous force that would be induced in the liquid over each unit of area of the inner surface. Then, numerically, $F = \mu'$. Now suppose the force, F, were to act unresistedly upon the mass contained in 1 unit of volume; the resulting accelerations would be given by:

$$\frac{F}{\text{mass in 1 unit volume of liquid}}$$

$$= \frac{\mu'}{\text{mass density of the liquid}}$$

$$= \text{"kinematic viscosity"}$$

Thus, the numerical value of the "kinematic viscosity" of a liquid equals numerically the number of units of acceleration of the mass of a unit volume of the liquid when acted upon, unresistedly, by the viscous force induced per unit area in a surface of the liquid where the velocity gradient was unity.

However, the foregoing numerical relationship does not alter the fact that the "dimensions" of kinematic viscosity are: velocity $\times$ distance.

The kinematic viscosity of a liquid can be derived experimentally by using apparatus of various types, called viscosimeters, by noting the time in seconds required for a given quantity of the sample liquid to flow out from a reservoir in the apparatus through a small vertical tube of definite dimensions. An idea of the principles underlying the determination of the viscosity of a fluid by the use of a viscosimeter can be obtained by a consideration of the flow of liquid through a vertical tube.

In Fig. 2 there is shown a perspective view of a vertical tube of length l, and inside radius R, through which a liquid is considered to be flowing downward in "laminar flow," the laminas or layers in being a series of concentric circular cylindrical shells whose radii successively decrease from R to zero at the center of the cross section of the tube. Consequently, each successive layer decreases in total area, for a given length l, as the center is approached.

The layer of very small thickness immediately adjacent to the inner wall of the tube may be considered to adhere to it and be virtually at rest, while the next inner layer moves downward with a certain uniform velocity because of the resistance offered by the viscous force acting over the inside surface of the relatively stationary layer. This kind of action continues throughout the entire liquid until the center is reached, where the downward velocity is a maximum.

Let h = the head of the liquid above the upper end A, and if w = weight of a unit volume of the liquid, then wh = pressure on the upper end A caused by the head of liquid above it.

Consider the forces acting downward on the body of liquid forming the cylinder of radius r and length l, as indicated by CDD, in Fig. 2. The total force on the upper end of the cylinder caused by the head pressure $= \pi r^2 wh$; also there is the weight of the cylinder of liquid $= \pi r^2 lw$; so that $w\pi r^2(h+l)$ = total downward force on the cylinder.

This force is balanced by the equal and opposite viscous force acting over

the outer surface of the cylinder, whose lateral surface $= 2\pi rl$. Hence in that surface of the liquid the shearing stress

$$= \frac{w\,\pi\,r^2\,(h+l)}{2\,\pi\,r\,l} = \frac{w\,(h+l)\times r}{2\,l}$$

If w, h and l remain constant, then the shearing stress in any cylindrical surface in the liquid varies directly with the radius of that surface, being zero at the center, and reaching a maximum value, $\frac{w\,(h+l)\times R}{2\,l}$ at the inner wall of the tube.

Let v = velocity of the layer or cylindrical shell whose radius is r. The velocity was stated to be a maximum at the center where the radius $= 0$; and as the radius increases to R, the velocity when $r = 0$, v is a maximum and equals

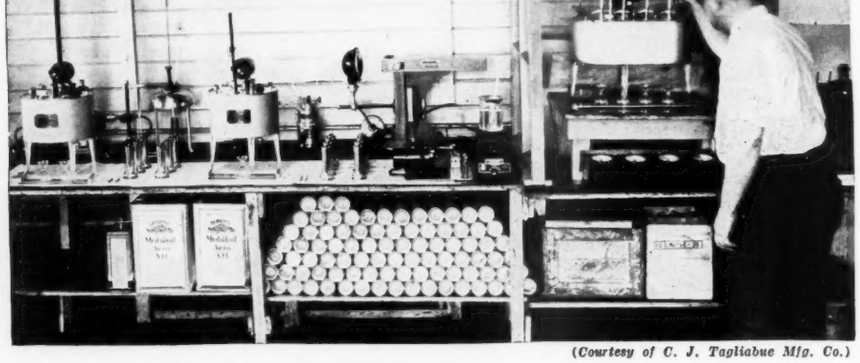
$$\frac{w\,(h+l)}{4\,l\,\mu}\,R^2$$

The volume of liquid in the thin cylindrical shell of radius r and moving downward at velocity v that would flow out of the tube in unit time equals $2\,\pi\,r\,dr \times v$; or by substituting the value of v in terms of r, this would equal:

$$\frac{\pi\,w\,(h+l)}{2\,l\,\mu}\,(R^2\,r\,dr - r^3\,dr)$$

Integrating this over the whole range of radii of cylindrical laminas from $r = 0$, to $r = R$, the total volume q, of the liquid passing out of the tube per unit of time is obtained, as follows:

$$q = \frac{\pi\,w\,(h+l)}{2\,l\,\mu}\left[\frac{R^2r^2}{2} - \frac{r^4}{4}\right]_0^R + b$$



(Courtesy of C. J. Tagliabue Mfg. Co.)

Fig. 4—Determining viscosity of sample liquids

according to some manner of variation, decreases to zero. Therefore at the surface of radius r, $-\frac{dv}{}$ represents the velocity gradient.

Letting μ = coefficient of absolute viscosity of the liquid, there results

$$\mu = \frac{w\,(h+l)}{2\,l}\,r \times \left(-\frac{dr}{dv}\right)$$

$$= -\frac{w\,(h+l)\;rdr}{2\,l\quad dv}$$

hence, $dv = -\frac{w\,(h+l)\;r\,dr}{2\,l\,\mu}$

whence,

$$v = -\frac{w\,(h+l)}{2\,l\,\mu} \times \frac{r^2}{2} + \text{a constant}$$

but $v = 0$, when $r = R$, and the constant above would equal

$$\frac{w\,(h+l)}{4\,l\,\mu}\,R^2$$

Therefore $v = \frac{w\,(h+l)}{4\,l\,\mu}(R^2 - r^2)$

Now $q = 0$, when $r = 0$, and the constant $b = 0$, therefore

$$q = \frac{\pi\,w\,(h+l)}{2\,l\,\mu}\left(\frac{R^4}{2} - \frac{R^4}{4}\right)$$

$$= \frac{\pi\,w\,(h+l)}{8\,l\,\mu}\,R^4$$

The time required for a given volume, Q, of the liquid to pass out of the tube

$$= \frac{Q}{q} = Q \times \frac{8l}{\pi\,w\,(h+l)\,R^4} \times \mu$$

Thus, the time observed for the quantity Q to flow through the tube would vary directly as the coefficient of absolute viscosity and inversely as the weight per unit volume of the liquid.

For the above liquid the mass density would $= w/g$.

Rewriting the foregoing equation so as to introduce the term of mass density of the liquid, there results

$$\text{the time required} = \frac{8\,l\,Q}{\pi\,(h+l)\,R^4 g} \times \frac{\mu}{\frac{w}{g}}$$

$$= \frac{8\,l\,Q}{\pi\,(h+l)R^4 g} \times \text{kinematic viscosity.}$$

Thus, with l, h and R unchanging the time required for the quantity Q to flow through the tube is directly proportional to the kinematic viscosity of the liquid. Several types of apparatus have been developed based on this relationship whereby the time of efflux of a definite quantity of liquid from a tube can be experimentally observed. Apparatus of this type are widely used in laboratories for the determination of viscosities of petroleum oils which practice has led to the custom of specifying viscosity by means of index numbers denoting time of efflux for standard volumes through standard tubes.

The American Society for Testing Materials has adopted as standard the Saybolt Universal viscosimeter. This instrument has a vertical efflux tube 0.483 ± 0.004 in. long and 0.0695 ± 0.0006 in. diam. Viscosities of lubricants are measured at 100 deg. F. and 210 deg. F., viscosities of fuel oils are measured at 77 deg. F. and 122 deg. F. The Saybolt viscosity of a liquid is the number of seconds of time required for 60 c.c. of the liquid to flow through the opening of a standard instrument.

For heavy oils the Saybolt-Furol viscosimeter is used; it differs from the Saybolt Universal apparatus in that the tube diameter is 0.1240 ± 0.008 in. The time of efflux of the Furol viscosimeter is approximately 1/10 of the Saybolt Universal apparatus.

With the Engler viscosimeter, an instrument in common use in Germany, the viscosity is expressed in "Engler degrees." The Engler scale of degrees is an arbitrary one which is determined by dividing the time of efflux of 200 c.c. of the liquid being tested by the time required for the efflux of the same quantity of distilled water at a temperature of 20 deg. C. (68 deg. F.) In the Engler instrument the outlet tube is 2.0 + 0.01 cm. long, the inside diam. of the tube is 0.29 + 0.002 cm. at the upper end and 0.28 + 0.002 cm. at the lower end.

Another viscosimeter of the tube type often referred to is the Redwood instrument which is used to a great extent in England. The Redwood viscosity of a liquid is the number of seconds of time required for 50 c.c. of the liquid being tested to flow through the outlet tube of the Redwood viscosimeter.

In Table II formulas are given by means of which the viscosities as determined by the three machines can be converted into metric and English kinematic viscosity units.

The Society of Automotive Engineers recommends the numbers shown in Table III as standard practice for designating the viscosity of crankcase oils.

STEEL TUBE CONSTRUCTIONS

Welded Frame and Body Designs

Prepared in collaboration with the engineers of Steel and Tubes, Inc., who furnished both the technical data and information with the examples of typical constructions shown here

IN THE FIELD of transportation the high cost of hauling dead weight has been receiving much study. Data derived from recent investigations show that revenue can be increased by cutting vehicular weight. Suffice it to say estimates indicate that the savings per pound reduction in dead-weight ranges from four to eleven cents per year for passenger carriers operating on highways and on rails. Weight consciousness has led to the widespread use of high strength alloys even at marked increase in initial cost. In many redesigns to decrease weight tubing, long recognized as the strongest structural shape for its weight, has played a prominent role. Also, increased use of tubing in new designs has been marked because of improvements in welding technique.

Brightly finished tubular furniture in restaurants, lobbies and public places has become a familiar sight in the last few years. The reason for this innovation was improved appearance at a reasonable price, the saving of weight being of little importance in such applications. Once the value of customer appeal was established for furniture of this construction, not much time elapsed before a demand was created for tubular seating in buses and other vehicles. With the use of tubing, benefits were two-fold; appearance was vastly improved and weight was cut, in many instances as much as 50 percent. Although steel tubing has been used for many years in the construction of bicycles and in airplanes, it was not until recently applied to other passenger carrying vehicles. So far as can be determined, tubing as a structural feature in design was pioneered in this country by the Stout En-

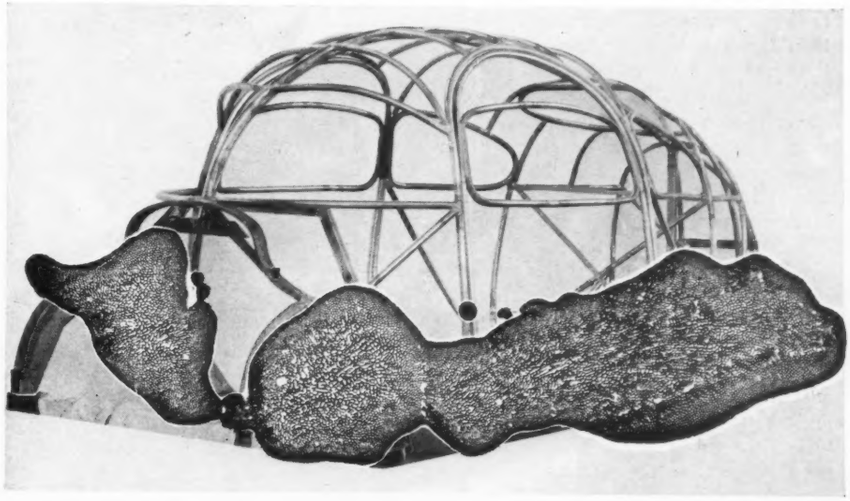


Fig. 1—Test model of "Aeromobile" with its 140-lb. frame which is all welded construction of 1 in. round 16 gage tubing

gineering Laboratories of Dearborn, Michigan.

In the construction of the "Scarab," Mr. Stout developed a chassisless tubular-frame automobile which, while extremely light, is very strong and rigid. With more passenger space than the average car, it is said to be more than 25 percent lighter than the average low-priced automobile of standard construction. The "Scarab" has individual wheel suspension similar to airplane landing gears. The tubular structure is assembled by welding. In the earlier cars which Mr. Stout produced, he used SAE-4130 (chrome-molybdenum) steel; recently he has found that the requirements for this service could be met by using SAE-1025 tubing.

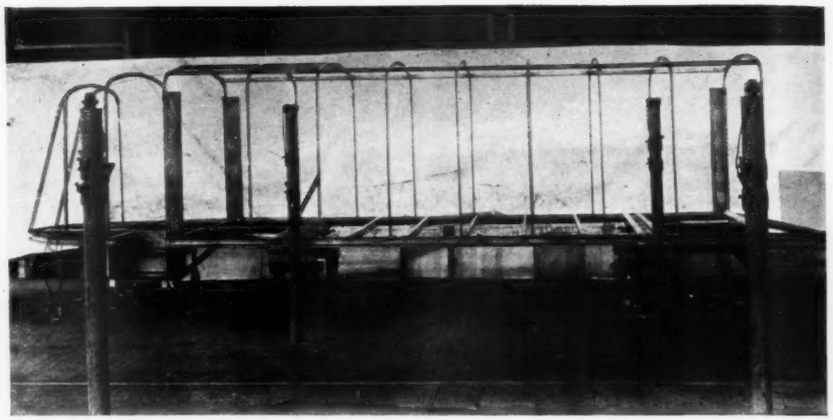
Mr. Stout is also credited with the design of a motor bus of chassisless construction that features steel tubing. This bus, built by the Motor Coach Division of Gar Wood Industries, Inc., is reported to be approximately 2,000 lb. lighter than the lightest conventional design of the same engine horse-power and seating accommodations. It was engineered by aircraft men and manufactured by a shop personnel trained in airplane factories. The total weight of the complete bus is less than 6,500 lb. and it has a seating capacity of 25 passengers. Most of the material used in the frame work is 1¼ in. square welded steel tubing. Some round sections are used at the front and the rear ends where it is necessary to bend the tubing in more than one plane. All of the joints in the frame are oxy-acetylene welded. The side sheets, roof, and bottom sheets are of 0.040 in. "Nicral" and are applied with self-tapping screws, thus making replacement in maintenance a simple matter.

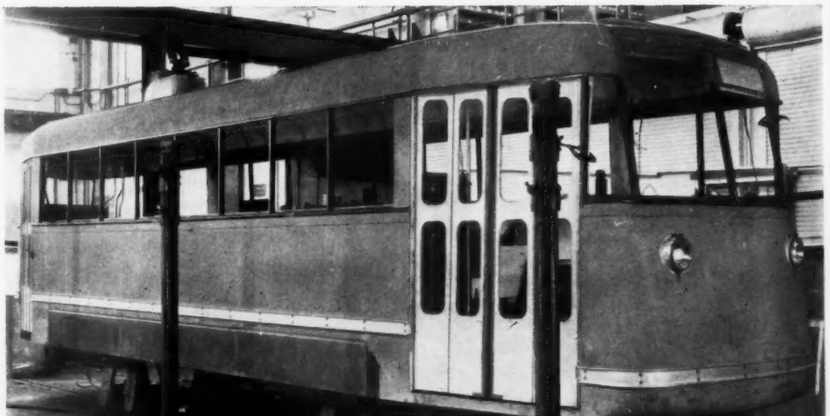
Ability to Take Shock

In a paper presented at the annual meeting of the Society of Automotive Engineers in January of this year, Mr. Stanley E. Knauss pointed out that ten years ago the production problems involved in welding a tubular framework of this size would have been considerable, but with the strides made in the last few years in the art of welding, it now seems almost impossible for a man with ordinary welding experience to make a poor weld. He also stated that these coaches had been in two major accidents, both of which proved, without any doubt, the ability of a steel tube structure to "take it." Under an impact of this nature, the welded tubular structure seems to absorb and localize the shock, which was demonstrated by the fact that with the exception of the wind-shield and one of the side wind-shield glasses, not one other window in the coach was cracked when travelling at a speed of more than 60 mi. an hr., it struck a five passenger sedan that appeared suddenly from a side road.

Just a little more than four years ago, Mr. H. S. Williams of the Detroit Street Railway developed an interesting and attractive design which had been in his mind for several years. He built a light-weight streamlined trolley car, the frame of which is almost entirely of 16 gage SAE 1010 steel tubing. In this design the side posts and roof bows are long tubes bent into the shape of hoops. Body sheets were attached by welding so that if damaged it would be a simple job to remove the distorted members with a cutting torch and weld in complete new sections of the frame. More than three years' service has demonstrated the practicability and economy of the design.

For several years now the Mack Motor buses and "all service" vehicles have featured tubular side posts of low carbon steel with 1.00 to 1.40 percent manganese content. This particular analysis was selected after exhaustive physical tests





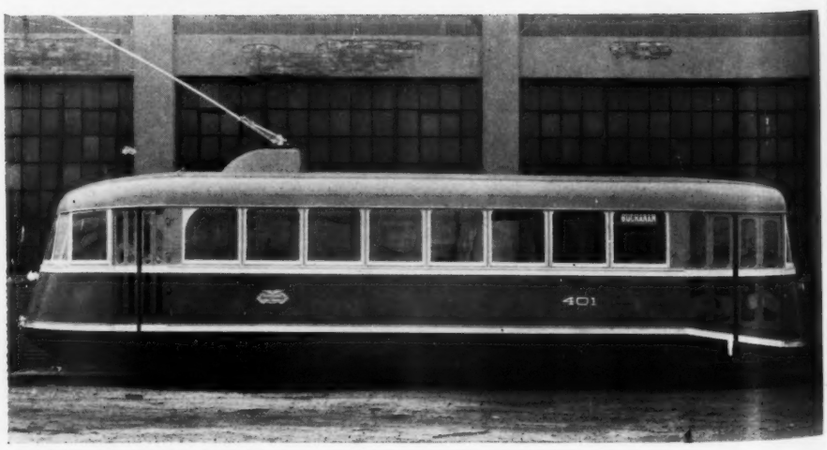


Fig. 2—Square and rectangular tubes were used in the construction of trolley car for the Detroit Street Railways, frame was arc welded, side sheets were attached by spot welding

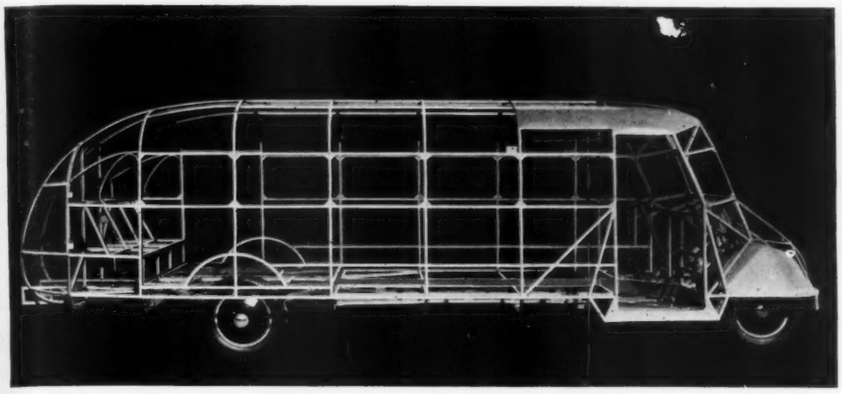


Fig. 3—Frame of Garwood Bus, welded unit construction with side sheets attached with self tapping screws

had determined that this material had the necessary fatigue strength. Mack has also decided that it is worth sacrificing the square corners on rectangular tubes, which were desired for the easy attaching of side sheets. They now use slightly rounded corners which have been found to give added resistance against fatigue.

During the past year or so, many bus body builders have come to the use of rectangular steel tubing for side posts. Some have gone a step further and use tubing for roof bows, carlines and stringers. One company has drawings and plans made up ready to start building a unit type bus body of steel tubular construction when the time is propitious.

Unit Construction

The Lewis American Airways Company of Denver, Colorado, has underway plans for the marketing of a three-wheel auto. The Aeromobile, as it will be called, will be powered by a 57 hp. four cylinder air-cooled opposed engine built by Doman & Marks of Syracuse, N. Y. The frame of the experimental model which was built in the Doman & Marks plant was constructed almost entirely of 1 in. x 16 gage round SAE 1010 steel tubing. All joints were oxyacetelene welded. The frame is of unit construction and each wheel is individually suspended. The entire frame weighs only 140 lb., which it is estimated can be further reduced as much as 20 percent with a few adjustments after more experimentation. It is reported that because of the efficiency of its power plant and the extreme light weight, the car has performed at an average of more than 33 mi. per gallon of gasoline in a 5,000 mi. road test.

In the field of passenger trailers, ever since its beginning on a commercial basis, the advantages of tubular construction have been recognized. While tubing has been widely used in the construction of chassis, its adoption in the design of the complete structure has been held back by the uncertainty of just what the future demand will be for this type of vehicle. If it is felt that the trailer field does hold a future for the manufacturers, steel tubing will undoubtedly come more and more into prominence in trailer construction. One important reason for this is that the unit construction idea lends itself more readily to this field than to any other since there is no engine, drive shaft or steering mechanism to complicate the structure.

In general the advantages that are inherent in the use of tubing can be most fully realized if, in the concept of design, tubing is considered functionally on its own merits and not as a substitute for other structural shapes. Such engineering will result in unit design or skin-stressed construction, of the type introduced and made famous by the designers of aircraft.

Fig. 4—Tubular constructions which combine ornament, utility and sanitary features. The interior of trolley car built to President's Conference Committee specifications

PREPARATION OF A RESISTANCE WE

J. M. COOPER
Welding Engineer, General Electric Company

Supplementing his article on page 334 of this issue, the author presents these design hints

FIG.1 FIG.2

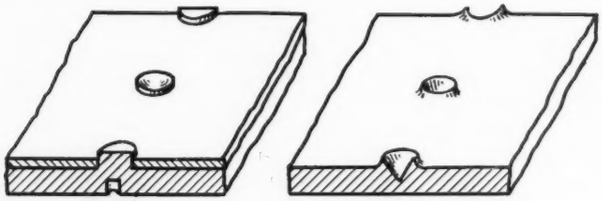


FIG.3 FIG.4

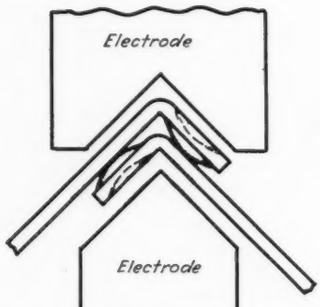


FIG.5

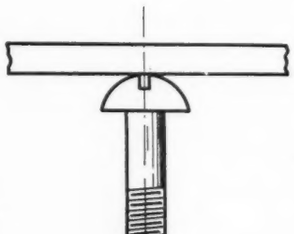


FIG.6

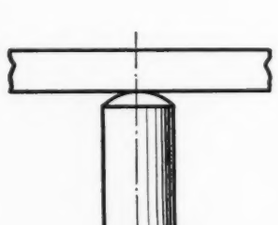


FIG.7

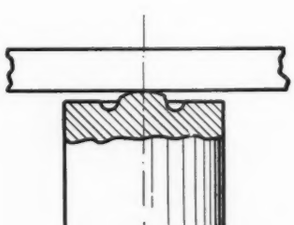


FIG.8

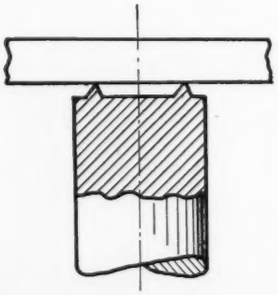


FIG.9

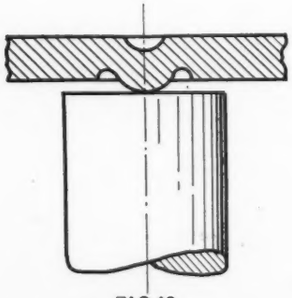


FIG.10

Fig. 1—Round, embossed projections make practical the use of flat electrodes. Several projection welds can be made simultaneously under the same large flat electrode. The larger area of electrode in contact with the work reduces current and pressure density on electrode, resulting in long electrode life.

Fig. 2—Typical pointed or cone-shaped projection, a form often used on light-gage materials such as 22 and 24 gage.

Fig. 3—Protruding punch-out may help to locate parts preparatory to welding. Where great strength is not required, the punch-out itself is sometimes electroforged down.

Fig. 4—Prick punch marks made with round punch (one blow) used in welding thick plates to light-gage sheets to throw up a crater which localizes welding heat and pressure.

Fig. 5—Design of embossed corners, formed over one another and welded between V-shaped electrodes. Self-aligning.

Fig. 6—Almost any form of screw, rivet or specially headed part can be projection welded.

Fig. 7—Slight radius on the end of the rod permits it to be welded to another part without throwing a fin or flash.

Fig. 8—The crater or ring-like cavity is filled with the heated metal of the round projection, resulting in close mechanical contact over the whole surface.

Fig. 9—A ring projection can be turned or coined on the shaft in order to localize the welding area.

Fig. 10—Construction similar to Fig. 8, except reversed, a crater projection combination being coined in the flat sheet.

Fig. 11—Projection swaged on the edges of a piece, a method of embossing thick plates or strap stock.

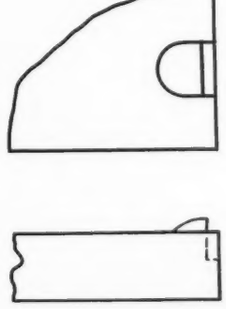


FIG.11

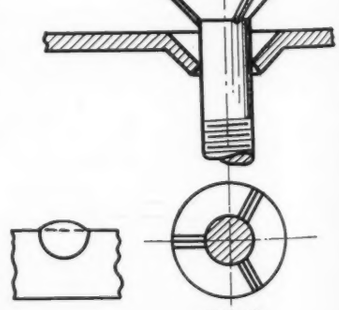


FIG.12

ORMATERIALS FOR CWELDING

Fig. 12—How specially headed screws or studs are prepared both to localize the weld and also to locate the screws without the necessity of using jigs or fixtures.

Fig. 13—Elongated projections that cross each other are recommended for the lightest gages and certain non-ferrous combinations, as well as for places where a good strong weld is imperative.

Fig. 14—Where possible, elongated projections or a pattern of ribs which cross one another, giving many points of small welded area, should be used for thin sheet metal.

Fig. 15—When projection welding to a curved surface, an elongated projection should be used. This is employed to assure ample contact surface in the direction in which movement is likely to occur.

Fig. 16—Upsetting a tube to form bulges can be done by heating and upsetting on a butt welder.

Fig. 17—Rods of almost any metal can be upset to provide increased sections or limiting rings.

Fig. 18—A method that helps to locate a spot-welded lap joint and also contributes to having one side of the object smooth.

Fig. 19—A method of welding both sides of a box form simultaneously, by employing a shunt block device.

Fig. 20—An example of "pry-bar" welding on a special machine. Done by prying against parts backed up by dies.

Fig. 21—Switch contacts of many different materials can be welded to their mounting members. This design shows a coined contact having three conical projections that nest in a ring groove stamped in the blade.

Fig. 22—When wire cables are "cut off" by clamping between the jaws of a butt welder and burning cable in two, a globule of metal, formed on the ends, holds the wires together.

Fig. 23—Pipe or heavy-walled tubes can be butted together or to other pieces. By chamfering pipe ends, the internal flash will be kept at the minimum.

Fig. 24—Rods or cables can be economically welded or swaged into sleeves or ferrules.

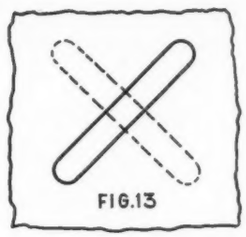


FIG.13

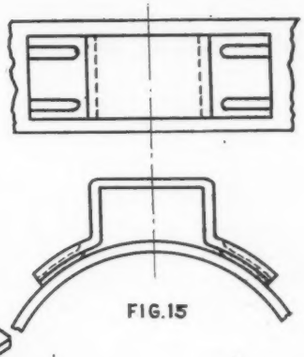


FIG.15

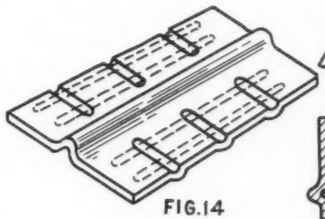


FIG.14

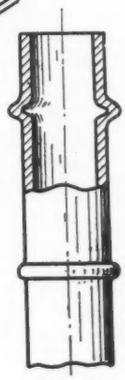


FIG.16

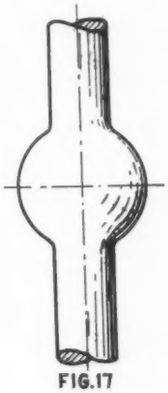


FIG.17

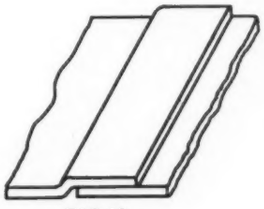


FIG.18

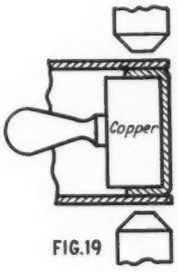


FIG.19

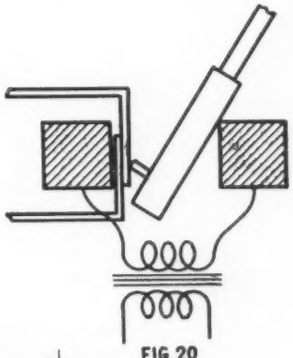


FIG.20

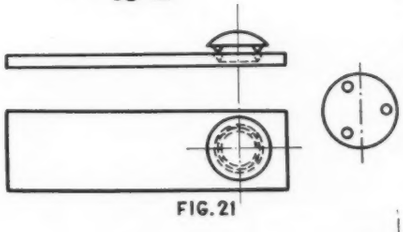


FIG.21

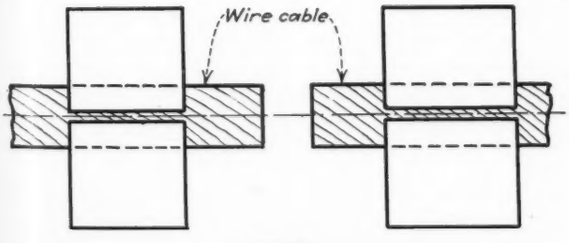


FIG.22

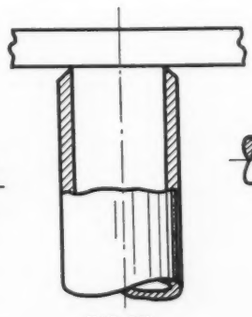


FIG.23

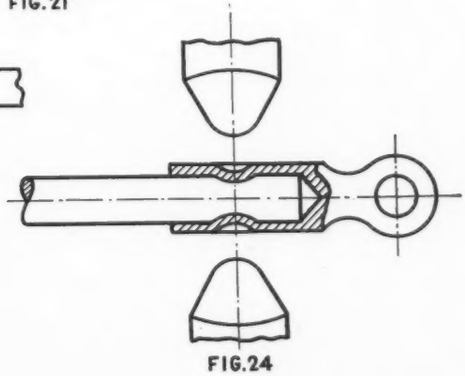


FIG.24

Question and Comment

More on Gear-Bore Proportions

To the Editor:

Application of Mr. Paul H. Black's interesting information on "Gear Bore Proportions," as mentioned in your June and July issues, to two cases brings up other factors.

First, as it is common practice with small generated pinions to enlarge the blank diameters, this same diameter increase might be added with safety to the formula for maximum bore. Thus, the pinion will have a maximum shaft size, as well as an improved tooth curve.

Similarly, for stub tooth pinions, twice the difference between the dedendum for the Brown & Sharpe tooth form and that for the stub tooth form might with safety be added to the maximum bore given by Mr. Black's formula. His opinion on this would be a valuable addition to his data.

Secondly, Mr. Black's stress investigations were no doubt made on pinions that were assembled on shafts with a clearance fit. If such pinions with maximum bores were assembled, as is common practice, with pressure fits, then dangerous stresses may be set up in the metal over the keyseat.

The writer's experience in this respect will serve as an example to show how a nominal push fit assembly on a maximum bore pinion may cause rupture. The pinion, having 13 teeth and a diametral pitch of 5, full depth, was made with a ⅛-in. diameter enlargement, giving a 3.125 in. outside diameter. The bore was 1-5/16 in. and the keyseat 5/16 in. wide. Dividing the number of teeth by the diametral pitch gives a 2.6 in. pitch diameter.

Using the pitch diameter plus ⅛ in. in Mr. Black's formula, published in your July issue, we find that the maximum bore could be 1.45 in. The actual bore, therefore, should have been safe. According to the Reference Book Sheet, in *Product Engineering* for November, 1933, the maximum bore could be 1⅛ in. and, according to Nuttall's formula a 1-5/16 in. maximum bore would be safe.

The actual pinions, of hardened alloy steel, were made with a push-fit allowance of only 0.001 in. in the bore, but, when assembled on the shaft, cracked through the metal over the keyway. The crack did not originate in one corner of the keyseat as might be expected.

In such a pinion, the strain due to the push-fit allowance will be concentrated in the metal over the keyway. In this case strain is $\pi \times 0.001$ in. in 5/16 in. of length, or approximately 0.01 in. in 1 in. of length.

The stress due to this strain is 29,000,- $\times$ 0.01, = 290,000 lb. per sq. in., approximately. Such a stress would, of course, rupture any gear steel, and even a tenth of this value would be a dangerous initial stress in a pinion.

This example shows how carefully these maximum bore gears should be designed and handled in the shop.

—P. N. Bland
Vancouver, B. C.

To the Editor:

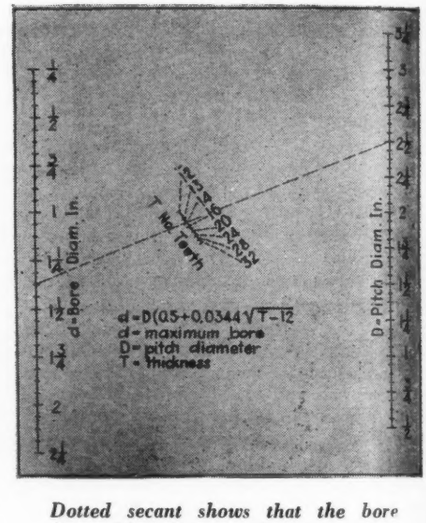
Photo-elastic experiments with Pyralin gears, as reported by Mr. Paul H. Black of the University of Illinois in your June and July issues, show that for a pinion with T teeth, having a keyway $d/4$ wide, placed on the center line of slot, with a pitch diameter D, there is a bore d such that the pinion will have equal strength at tooth and hub.

The relation between the quantities, within the range tested, is expressed by the empirical equation:

$$d = D\ (0.5 + 0.0344\ \sqrt{T - 12})$$

By means of the accompanying Z-chart, this equation can be solved by a single secant cutting the three scales.

—Carl P. Nachod
Louisville, Ky.



Dotted secant shows that the bore for a 14-tooth gear of 2½ in. pitch diameter should be 1⅜ in. maximum

Preserving "Dope" Sketches

JOHN E. HYLER
Peoria, Ill.

When an experimental job is in progress, it is sometimes developed partly in the shop and partly on the drafting board, the engineering department and the shop feeling their way along together —especially if and when the job is a radically new thing.

At times, such a procedure is practical, although it may not be the last word from the theoretical standpoint. The first completed job will be rough, and will need a thorough going over to "iron out the wrinkles" afterward. There may be certain things about the design that will call for further development on the drafting table, and to this end it is important that data on the job be kept in graphic form as much as possible.

Under such circumstances, the draftsman can usually make crude free hand sketches in the shop on ordinary pads of scratch paper, and keep them until he is ready for further development. In our experience, such "dope" sketches are very helpful. There are other instances, as well, when the making and preserving of dope sketches is helpful in preventing original ideas which occur to the designer from time to time, from eluding him later when he wants to put them to practical use.

At one time, it was not a real task to store such sketches in an orderly manner that would assure against their being lost or, at least, against their being "filed" in a place where they were almost

impossible to find on short notice.

A looseleaf notebook and an ordinary small office stapling machine were found to be the answer. Coming in from the shop with a number of dope sheets related to a given subject or a given machine, the designer now finds it but the work of a moment to put a looseleaf into the typewriter, write upon it any notes desired in connection with the rough sketches that have been made, and then staple the sketches directly to the looseleaf book.

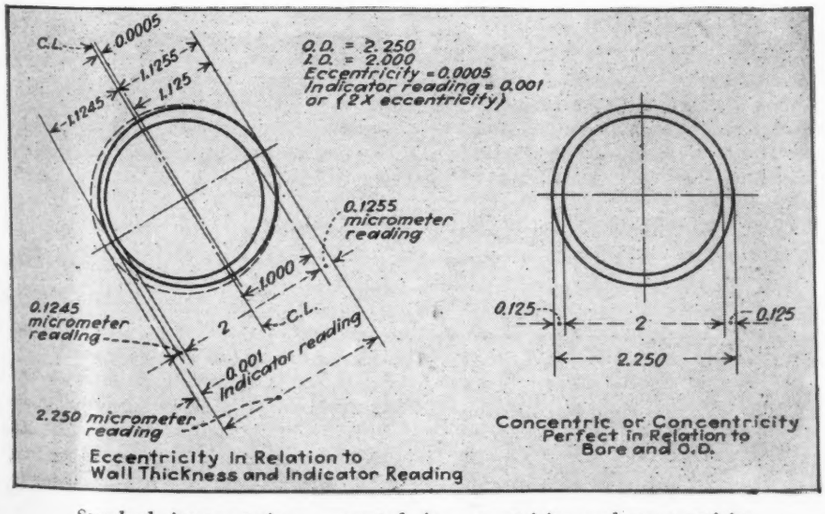
Now, there is no chance of losing any of the sketches. Those relating to different jobs or different subjects have no opportunity of getting shuffled together and causing confusion. One job, one looseleaf, whether there be one sketch or two dozen.

Specifying Concentricity

ROBERT G. N. EVANS
Toledo, Ohio

The terms "concentric" and "concentricity" are generally misused, I think, because of a lack of understanding of the meaning. For example, in laying out a sleeve bearing, the draftsman or engineer will specify "concentric within plus or minus 0.0005 in." Another will specify "concentricity 0.0005 in." and still another will specify "eccentricity 0.0005 in." According to my interpretation, the last-mentioned specification is correct if the engineer wanted an 0.001 in. indicator recording.

There is considerable confusion in respect to these terms and I think the meaning should be standardized. For this reason I suggest a standard interpretation, as shown by the accompanying drawing, and ask that it be considered by your readers.



Standard interpretations suggested for eccentricity and concentricity

Solution to Problem on Angular Velocity

To the Editor:

In the following paragraphs, I submit a solution to the angular velocity problem, presented by Mr. H. W. D'Entremont in your August issue, wherein it is desired to find the relative velocity of the two angles used in constructing an ellipse.

Using the same notations as given in the original problem, we can establish the following relation:

$$\tan \beta = \frac{y}{x} \qquad (1)$$

$$y = r \sin \alpha$$
$$x = r \cos \alpha$$

Substituting these values for x and y in Equation (1), we have:

$$\tan \beta = \frac{r}{R} \tan \alpha \qquad (2)$$

Differentiating with respect to α,

$$\sec^2 \beta \frac{d\beta}{d\alpha} = \frac{r}{R} \sec^2 \alpha$$

$$\text{or } \frac{d\beta}{d\alpha} = \frac{r \sec^2 \alpha}{R \sec^2 \beta}$$

The $\sec^2$ of any angle is equal to one plus the $\tan^2$ of the same angle. Hence:

$$\frac{d\beta}{d\alpha} = \frac{r\,(1 + \tan^2 \alpha)}{R\,(1 + \tan^2 \beta)}$$

However, from Equation (2), we have:

$$\tan^2 \beta = \frac{r^2}{R^2} \tan^2 \alpha$$

Substituting and simplifying,

$$\frac{d\beta}{d\alpha} = \frac{R\,r\,(1 + \tan^2 \alpha)}{R^2 + r^2 \tan^2 \alpha}$$

This is the desired equation and can be solved for all values of α except $\pi/2$ and $3\pi/2$ when it is indeterminate. To solve for these values, divide both numerator and denominator of the fraction by $\tan^2 \alpha$.

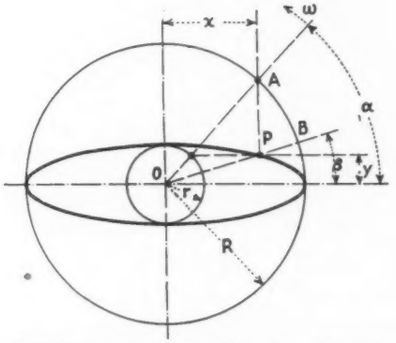
Then when α is equal to $\pi/2$ and $3\pi/2$,

$$\frac{d\beta}{d\alpha} = \frac{R}{r}$$

When α is equal to zero and π,

$$\frac{d\beta}{d\alpha} = \frac{r}{R}$$

—EDGAR H. SCHMIDT,
New York, N. Y.



***Required:** An expression for the rate of change β with respect to α at any value of α from 0 to 2π*

[*Editor's Note*: A solution to this same problem was also submitted by Mr. Ralph M. Watson of South Orange, N. J. However, instead of differentiating Equation (2) as above, Mr. Watson first transformed it to the following form:

$$\beta = \tan^{-1} \frac{r}{R} \tan \alpha$$

After differentiating β with respect to α and rearranging slightly, the following relation is obtained:

$$\frac{d\beta}{d\alpha} = \frac{1}{\frac{r}{R} \cos^2 \alpha + \frac{R}{r} \sin^2 \alpha}$$

As will be seen upon inspection this solution, though in different form, is the same as that submitted by Mr. Schmidt. An equivalent solution was also received from Mr. Walter F. Burke of Hampton, Va.

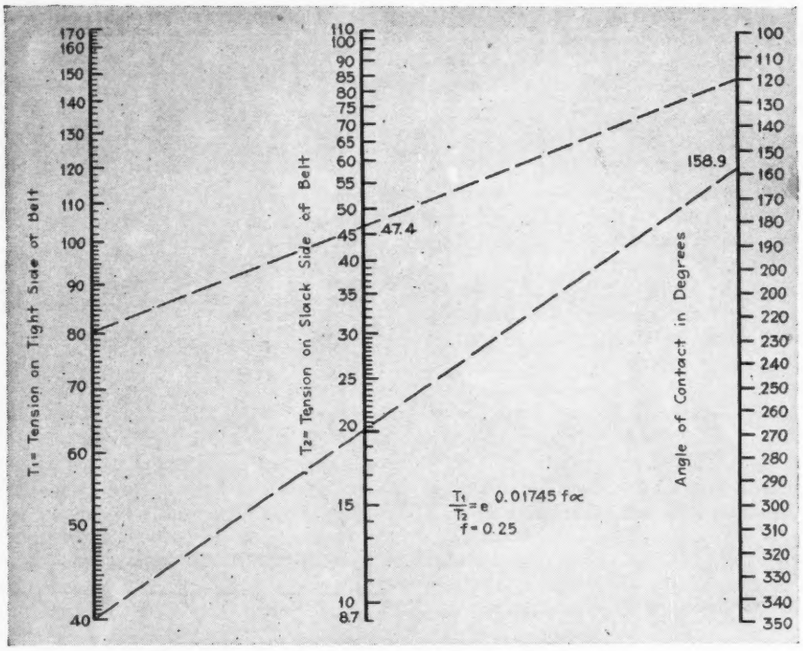
By differentiating Equation (2) above with respect to time, Mr. J. J. Pesqueira of New York City obtained the following relation:

$$\frac{d\beta}{dt} = Q \frac{\sec^2 \alpha}{1 + Q^2 \tan^2 \alpha} \omega$$

$Q = r/R$

ω = angular speed of ray $O\,A$

Mr. Pesqueira points out the interesting fact that the motion of the ray OP may be easily realized in practice. "In



Nomographic chart giving resistance of belt to slipping

fact," he writes, "it may be shown that the motions of the rays *OA* and *OP*, respectively, are precisely the motions of the two members of a pair of elliptical gears having axes of rotation through the centers of the ellipses, these ellipses being identical to each other and geometrically similar (same eccentricity) to the ellipse of the problem."

Mr. Frederick W. Seybold of Westfield, N. J., who also contributed an equivalent solution, comments:

"It will be found that the minimum angular velocity ratio of the rays *OA* and *OP* is always the reciprocal of the maximum angular velocity ratio, and the latter is always equal to the ratio of the major axis of the ellipse to the minor axis of the ellipse."

Small Portable Gas Engine

To the Editor:

For some time we have been trying to locate a manufacturer making an extremely light ½ hp. air-cooled gasoline engine for use with a very portable piece of forestry equipment we are designing. The total weight of the engine should not exceed 15 lb. complete with ignition system, gas tank, and a supply of fuel to last at least three hours. Preferably it should operate with the crankshaft in a vertical position, although a horizontal shaft could be used provided the total weight is low enough to allow for the addition of a bevel-gear takeoff.

It is hoped that one of your readers will be able to suggest where such an engine can be obtained. —C. V. S.

Madison, Wis.

More on Resistance of Belts to Slipping

To the Editor:

There apparently is an error in the nomogram published with Mr. Salvatore F. Cavalli's comments in your June issue on "Resistance of Belts to Slipping."

On the chart the value for angle of contact, when T_1 equals 40 lb. and T_2 equals 20 lb., reads about 174 deg., whereas by calculation it is found to be 158.94 deg. I believe the log chart for T_2 is in error in the lower half.

Incidentally, there is also a typographical error in the formula printed on the right-hand column of page 228 for T_1/T_2, which, instead of being equated to $e^{f\alpha}$ should be equated to $e^{f\alpha}$ as is correctly shown on the nomogram which accompanied the discussion. In other words, α should have been printed as an exponent.

When Mr. Cavelli's comments came off the press, I had a belt problem and proceeded to make up my own nomogram in a slightly different form. After it was completed, it would not check with Mr. Cavelli's, but I find mine is correct. —Horace W. Jones

Chicago, Ill.

To the Editor:

Mr. Jones is correct; the nomogram published in the June issue is in error. Herewith is the correct chart as I originally drew it. Apparently, it was distorted when I had a tracing made to send to you. A dotted line has been added for the values referred to by Mr. Jones, and it will be seen that the result agrees with his calculations. I regret that the error occurred.

—Salvatore F. Cavalli

Dover, N. J.

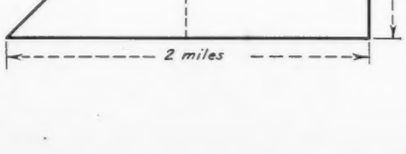
Can You Work This One?

H. E. SMITH

This Month's Problem—

Trig Teaser

A farmer owned a section and a half of land which, because of a highway that cut diagonally across the county, was made up of one square section and an adjacent triangular half section, as shown in the accompanying sketch. In making his will, the farmer wished to divide the land impartially among his four sons. Each son, he decided, should inherit a parcel of land not only of the same area but also of the same shape as the other three. How could the land be thus divided?



Solution to Last Month's Problem

Dollars and Cents

Let X be the number of dollars and Y be the number of cents in the amount for which the check was written. Then, $100 \times X + Y$ is the amount in cents for which the check was written, and $100 \times Y + X$ is the amount in cents received.

After spending $1.93, the man found that he still had two times as much left as the check originally called for or, in cents, $2\ (100 \times X + Y)$. This is equal to the amount received minus $1.93 or, in cents, $100 \times Y + X - 193$. By equating and solving, it will be found that $X = 1$ and $Y = 4$. Therefore, $1.04 is the amount for which the check was originally made out.

News

Oppose Planning Board to Regulate Invention

REFERRING to the 450,000 word report on "Technological Trends and National Policy," issued by the National Resources Committee and proposals to set up a national planning board to regulate inventions and mechanical progress, the Machinery Institute states:

"History has proved that society has more to gain than lose by freedom in the development of inventions and their application. Desirable as it might be to foresee the development of an invention, experience indicates that this is impossible, to say nothing of planning for the unpredictable results. Even the scientists themselves admit that those who have been considered most competent to judge the future of inventions have been wrong about as often as uninformed guesses would have been. Incalculable damage would be done if society had a method of officially vetoing the 'hunches' of such men as Edison and Ford.

"The most common fallacy in connection with technological development is to assume a direct relationship between productivity of a new machine or process and employment."

The report on "Technological Trends and National Policy" is in effect a successor to the Hoover Report "Recent Economic Trends." The intent of this report is to summarize in a general way the extent to which present technological trends will, within the next 20 years, affect society and government. The book is divided in three parts: Part I—Social aspects of Technology, Part II—Science and Technology, Part III—Technology in Various Fields. Those who contributed to this report include William S. Ogburn, S. C. Gilfillan, Bernhard J. Stern, David Weintraub, John C. Merriam, Edward G. Elliott, Harold A. Osgood, A. A. Potter, M. M. Samuels, Harrison E. Howe, Andrew W. Cruse, C. C. Furnas, and many others. The report recommends the establishment of a board which would keep track of developments in thirteen fields including synthetic rubber, plastics, the mechanical cotton picker, air conditioning, television, photoelectric cells and other new developments that give promise of great progress in the immediate future. Some of the report recommendations are that studies of the most important invention be made by planning agencies suggested, or by existing planning boards, and that a joint government committee should be formed to watch and report on technological unemployment. The committee stressed the need for a permanent federal planning board which would be coordinate for the many planning boards now in existence, these including 47 state boards, 400 county boards and 1,100 city boards.

With reference to new inventions, the report points out that while technological unemployment is the result of many new inventions, there is compensation in the new job created by the invention.

In commenting on this conclusion, the Machinery Institute states:

"The most common fallacy in connection with technological development is to assume a direct relationship between productivity of a new machine or process and employment.

"Since the beginning of the century output per worker in the iron and steel industry has increased more than 60 per cent, but instead of employment declining it has increased more than 100 per cent. There are machines enough in the American textile industry to spin more yarn and weave more cloth than could be made by all the women in the United States using the methods of Colonial housewives. Yet there have been more workers employed in the textile industry in recent years than ever before in history. These examples are typical of dozens which could be cited to show the tremendous increases in employment which have taken place while output per worker has increased."

Reporting on a series of studies made by Machinery Institute on the relation of inventions to employment and living standards, the Institute found a close relationship between economic well being and the use of inventions in the various parts of the United States, as well as in nations of the world.

"Michigan, where aggressiveness in developing new inventions and instituting technological improvements is probably greatest, has the highest weekly factory wage in the United States, according to Department of Commerce reports," the Institute stated. "In per capita income, New York, because of the concentration of financial activity in New York City, ranks first, but it is followed next by Connecticut which, with Rhode Island, is at the top in industrialization, measured by relation of manufacturing income to total income. Rhode Island's per capita income is exceeded only by three other states, one of which is California whose motion picture stars owe their fortune to technology.

"Mississippi, an agricultural state, which has the lowest per capita income in the nation, ranks at the bottom in percentage of farms equipped with tractors and almost at the bottom in per capita horsepower used by its industries."

As might be expected, the report by the National Resources Committee is inaccurate in spots with reference to technical facts and although most engineers will disagree with many of the conclusions and recommendations, those who study the report with an unprejudiced mind will agree that William F. Ogburn, professor of political science, at the University of Chicago, who directed the research, did a remarkable and very noteworthy job.

New A.S.T.M. Committees on Glass and Plastics

THREE new standing committees were organized during the 1937 annual meeting of the American Society for Testing Materials held in New York City. A new standing committee designated as D-6 will study, review and adopt general paper testing methods and investigate specifications for paper and paper products. Another new committee, designated as D-20, will work in the field of plastics toward the development of testing methods applicable to that field. This committee will develop methods for testing molding powders, standard shapes such as sheets, rods and tubes, and for testing finished molded articles.

In line with the proposed activities of this committee, five subcommittees were organized and chairmen were appointed as follows: Subcommittee I on strength properties, H. M. Richardson of General Electric Co.; Subcommittee II on hardness properties, J. C. Pitzer of Formica Insulation Co.; Subcommittee III on thermal properties, L. N. Currie,

of National Carbon Co.; Subcommittee IV on optical properties, H. W. Paine, E. I. du Pont de Nemours & Co.; Subcommittee V on permanence properties, G. M. Kline, National Bureau of Standards.

As one of its first important projects, the committee accepted the responsibility of preparing for a symposium on plastics which is to be held as the technical feature of the 1938 regional meeting to be held in Rochester, N. Y.

A new standing committee on glass and glass products has been designated as C-14. The purpose of this committee includes the development of nomenclature and methods for analysis and testing of glass, both as such and as specific products. Dr. Morey, of the Geophysical Laboratory of the Carnegie Institution of Washington, was elected chairman and Mr. Lewis Navias, of the General Electric Co., Schenectady, N. Y., was elected secretary, and F. C. Flint, of Hazel-Atlas Glass Co., was elected as vice-chairman.

Six subcommittees and their respective chairmen were appointed as follows: I. Nomenclature and Definitions, E. W. Morey; II. Chemical Analysis, G. E. F. Lundell of the National Bureau of Standards; III. Chemical Properties, D. E. Sharp, Hartford-Empire Co.; IV. Physical and Mechanical Properties, J. T. Littleton, Corning Glass Works; V. Thermal Properties, E. W. Tillotson, Mellon Institute of Industrial Research; VI. Glass Construction, Block and Tile, J. P. Staples, Pittsburgh-Corning Corp.

The personnel of the committee is made up of prominent technologists in the industry representing producers and consumers, and, in addition, a number representing general interests.

Drawings for V-Belt Pressing Machines

WORKING drawings have been prepared by the Society of Automotive Engineers' Standards Committee from which a machine can be constructed to test V-belts by the methods given in the new S.A.E. standards for V-belts and pulleys as set forth on pages 60-63 of the 1937 S.A.E. Handbook. The design of this fixture was made as simple as possible so as to give uniformly comparable results and long service.

Designated by the Numbers S.A.E. 7-7-10 and 7-7-11, the drawings are available to members of the Society at 50 cents per set and to non-members at $1 per set. Orders should be addressed to the Standards Department, Society of Automotive Engineers, 29 West 39th St., New York.

Use Device to Test Thickness of Paint Films

IN ORDER to establish an accurate check on the thickness of the lacquer or enamel coatings on all parts of the automobile body, the Studebaker Corporation has put into use a new electrical inspection device. This instrument gives a direct reading which indicates the thickness of the film being tested as compared to a film of known thickness.

Operation of the film thickness gage is based on the principle of balancing an unknown electrical resistance against a known resistance. The dial of the gage registers the difference in resistance between that of an established standard thickness of paint and that of the surface under test. It is merely necessary to hold the gage terminal against the paint surface to be tested and read the result directly on the dial.

With the ever increasing importance that is being attached to durable finishes and with the availability of simple inspection devices such as this one, it is thought likely that the checking of paint film thickness will become general. This would eventually lead to specifying the required film thickness by the engineering department.

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MEETINGS

NATIONAL METAL CONGRESS—*Held in conjunction with the National Metal Show and participated in by five international societies, the American Society for Metals, the Iron & Steel Division, and the Institute of Metals Division of the American Institute of Mining & Metallurgical Engineers, the American Welding Society, the American Society of Mechanical Engineers, and the Wire Association. W. S. Eisenman, managing director, 7016 Euclid Ave., Cleveland, Ohio.*

American Gear Manufacturers Association — Annual meeting, Lake Wawasee Hotel, Lake Wawasee, Ind., Sept. 20-22. J. C. McQuiston, secretary, Penn Lincoln Hotel, Wilkinsburg, Pa.

Porcelain Enamel Institute—Annual meeting at Chicago, Ill., Oct. 11-12. Geo. P. MacKnight, secretary, 612 N. Michigan Ave., Chicago, Ill.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—*Fall meeting, Erie, Pa., October 4–6. Ernest Hartford, assistant secretary, 29 West 39th St., New York City.*

EXPOSITIONS

CHICAGO EXPOSITION OF POWER AND MECHANICAL ENGINEERING — *International Amphitheatre, Chicago, Ill., October 4–9. Charles F. Roth, manager, Grand Central Palace, New York City.*

NATIONAL METAL SHOW—*Atlantic City Auditorium, Atlantic City, N. J., October 18–22. W. S. Eisenman, director, 7016 Euclid Ave., Cleveland, Ohio.*

NATIONAL AUTOMOBILE SHOW—*Grand Central Palace, New York City, October 27-November 3. Alfred Reeves, manager, 366 Madison Ave., New York, N. Y.*

Porcelain Enamel Forum at Ohio State

IMMEDIATELY following the seventh annual meeting of the Porcelain Enamel Institute which will be held in Chicago, October 11 and 12, the second Porcelain Enamel Institute Forum will convene at the Ohio State University at Columbus, Ohio, with sessions to be held from October 13 to October 15 inclusive. By having the annual meeting and forum during the same week, it will afford an opportunity to those attending either one to take in both of the functions without incurring undue expense. Both of these meetings are open to everyone in the industry.

The tentative program for the forum includes papers, discussions and reports on enamel shop costs, incentive systems for enamel shops, safety and plant maintenance, welding, cleaning compounds, nickel treatment of enameling iron, enamel process inspection and repair, colors and color matching, structural porcelain enamel, the silk screen process, control and consistency of enamel for chipping, and numerous other papers.

Do You Know That—

HOLES as small as 0.010 in diam., walls of only a few thousandths thickness, tolerance of plus and minus 0.001 in. are claimed for a new casting process just announced. With practically no limitations as to undercuts, this process makes possible surface finishes as smooth as those obtained by die-castings, with corresponding fine surface definition, and the cast metal, brass, bronze or other metals, is remarkably malleable. (58)

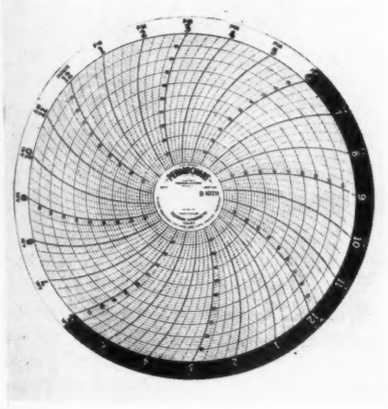
ALUMINUM coated iron and steel is now available as the result of a new process wherein the steel at high temperature is kept in an atmosphere of hydrogen and then immersed in molten aluminum. The bonding surface between the aluminum and steel is in the form of a complex alloy. (59)

STAINLESS steels are regularly supplied in eight standard finishes, the finest of which has a mirror-like surface. (60)

New Materials and Parts

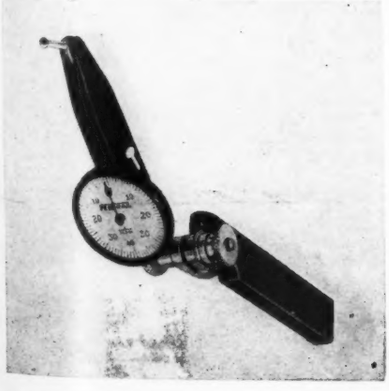
Recording Meter Chart

A smooth, hard-surfaced chart, known as the "Permochart," for use in all cases where ordinary paper charts are destroyed after one day's use. Is made from a recently developed wrinkle-proof, water-proof, non-inflammable material and can be cleaned with a damp cloth. Actual tests have proved the charts effective for more than two years. Charts can be made to fit all types of recording instruments for flow, temperature, pressure and vacuum, humidity, electricity, motion, speed, etc. Permochart Co., Koppers Bldg., Pittsburg, Pa.

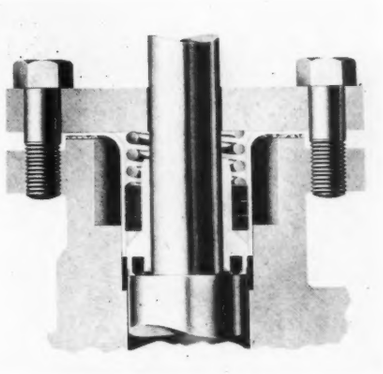


Small Test Indicator

"Model 2" low-friction jeweled bearing test indicator equipped with universal holding bar and clamp. The instrument has a range of 0.008 in. and is graduated to read 0.0001 in. The movement consists of a combination lever and direct contact crown gear to reduce friction and wear to a minimum. It can be used in surface gages, height gages or tool posts and is quickly adapted to special fixtures. Federal Products Corp., 1144 Eddy St., Providence, R. I.



Shaft Seal



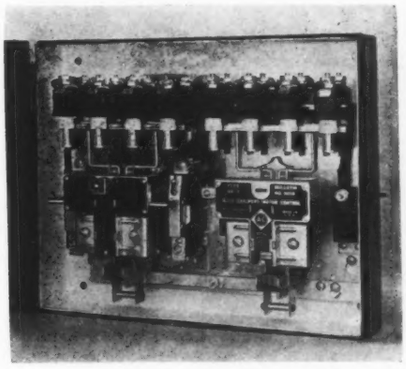
For eliminating the leakage of gases and liquids around the rotating and oscillating shafts of compressors and pumps. Advantages claimed for this new seal are the entire elimination of leakage over a long period of time without adjustment, self-seating action, self-lubrication and self-centering. Supplied complete, ready for installation, including the seal nose piece, packing rings, compression spring, seal housing and gasket. Syntron Co., 240 Lexington Ave., Homer City, Pa.

Burn-Proof Lacquer

A new baking lacquer, known as Durtemp, that withstands the action of match flames, lighted cigars and cigarettes, and also perfumes, alcohol and household chemicals. It is a gold colored clear lacquer applied to metals by dipping or spraying and is then baked. Maas & Waldstein Co., Graybar Bldg., New York, N. Y.

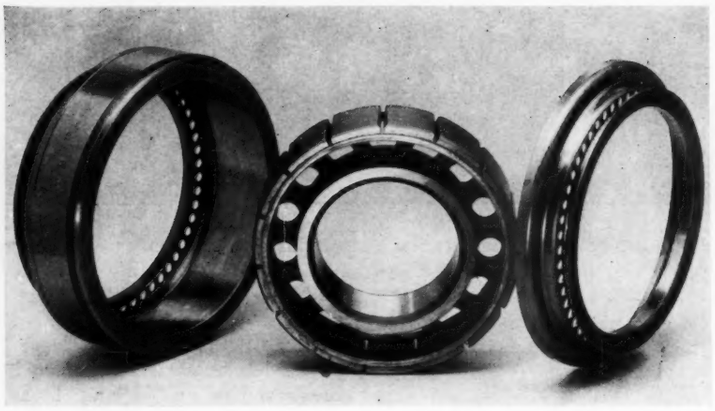
Reversing Motor Starter

Designated as type AP-7-R, furnished for 7½ hp., 550 volts, or less. The starter consists of two type AP-7 motor starter units, mechanically interlocked so that either unit cannot be closed if the other is closed. The starter units are equipped with Ruptors which consist of inclosing chambers which confine and depotentiate the arc formed by circuit interruption, greatly increasing the interrupting ability of the contacts and forming individual isolating barriers between contacts of opposite polarity. Other features include large silver double-break contacts, solenoid operated, vertical make and break, unit construction, pole units consisting of individual molded bases mounted on a steel chassis and overload and undervoltage protection. Allis-Chalmers Mfg. Co. Condit Works, Boston, Mass.



Improved Pillow Block

Ball bearing rubber pillow block of improved design using the Fafnir wide inner ring ball bearing with its self-locking collar. This feature makes for easy installation. The shaft is slipped through the bearing unit, the self-locking collar is engaged and turned, and the setscrew tightened. The bearing is then firmly secured to the shaft. Removal is equally easy. Also includes all the other features of the line of ball bearing rubber pillow blocks recently announced. They are built to inch dimensions and fit standard shafts without machining. Offered in sizes ranging from ½ in. to 1-7/16 in. bores. The Fafnir Bearing Co., New Britain, Conn.

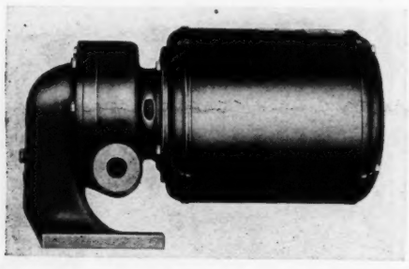


Precision Oil Film Bearings

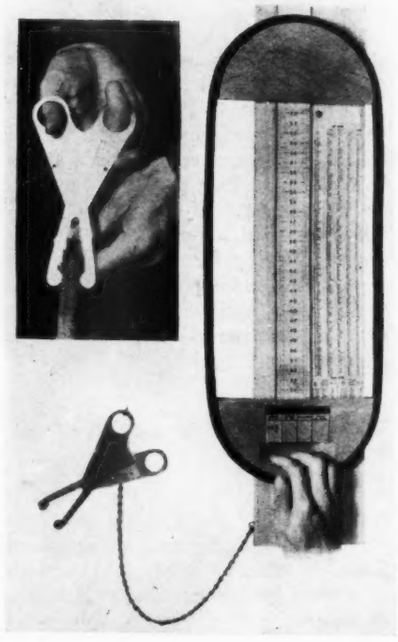
A new special design of bearing with an oil reservoir in the base. The inner member of the bearing has integral shoes or blocks as shown in the illustration, the blocks being slightly tilted to permit wedge-shaped multiple oil films. The outer member has an unbroken bearing surface. Inner member rotates with the shaft and also acts as a pump which furnishes oil under pressure to the bearing surfaces with the result that the bearing is carried on a perfect film of oil. The bearing sleeve or outer race is made a light press or drive fit in the housing while the journal hub or inner race is mounted on a shaft by means of a shrink fit, neither lock washers nor lock nuts being required. Available in cylindrical type and spherical type for thrust or location bearing. Usual application requires one cylindrical and one spherical bearing. These bearings are interchangeable with any ball or roller bearing made to internationl standard dimensions of the same series. Available in a range of sizes up to 5.9055 in. bore diam. The Fast Bearing Co., Baltimore, Md.

Vertical Bracket Coolant Pump

A compact, self-contained unit, known as model "VB", which bolts directly to the side of the machine base or coolant reservoir. Developed for use in handling coolant or lubricant for machine tools, although any type of liquid not too highly corrosive or viscous may be pumped. It requires no suction piping. The intake is directly through the base bracket. No relief or by-pass valves are need in the delivery line. Any degree of throttling may be accomplished without increasing the load on the motor. Pioneer Engineering & Mfg. Co., 31 Melbourne Ave., Detroit, Mich.



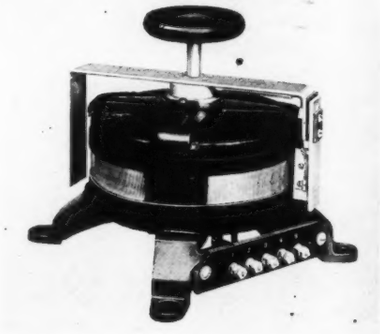
V-Belt Gage



For the measurement of circumference, angle, width and thickness of V-belts, the measurements being made as indicated in the illustration. The upper half disk is fixed while the lower half disk slides along a graduated scale. The calipers give direct readings of angle and are graduated every 2 deg. from 20 to 60 deg. The graduations for width and thickness are 1/16 in. from 0 to 2 in. The calipers are obtainable as a separate item. Calibron Products, Inc., West Orange, N. J.

Voltage Regulator

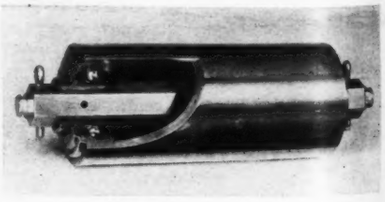
An improved voltage regulator, known as Type TH Transtat, for alternating-current circuits of relatively low voltage and limited capacity. Available in various standard sizes for controlling voltage to loads up to 2.5 kva. on either 115 or 230-volt lines. In construction, the regulator consists of a transformer coil surrounding an annular steel core. A carbon brush is arranged so that it can be rotated in continuous contact with a commutator formed on the winding by removing insulation from the wire in a narrow track around the circumference. Voltage is varied by rotating the brush which makes contact between the transformer winding and the load. Continuous control of voltage is possible.

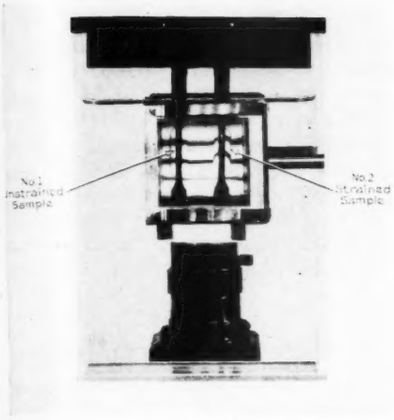


Type TH Transtat regulators are particularly suited for applications in industrial, laboratory and radio work and for use with electrical equipment as a control of voltage, illumination, motor speed, or heat. American Transformer Co., 178 Emmet St., Newark, N. J.

Heavy-Duty Roller Conveyer

Type 47-SB, made of 3½ in. O.D. seamless steel tubing with 5/16 in. wall. Bearings have steel inner and outer labyrinth seals, hardened ball races and 13-9/16 in. diam. hardened steel balls, assembled within a pressed steel jacket. Axle is hexagon shape which provides a positive means of locking the inner ball race and the axle. Axle ends are drilled for grease fittings and cotter keys hold the roller in the frames. Available in lengths ranging from 6 in. up to 48 in. Average rated capacity is 2,200 lb. Mathews Conveyer Co., Ellwood City, Pa.





Glass Strain Analyzer

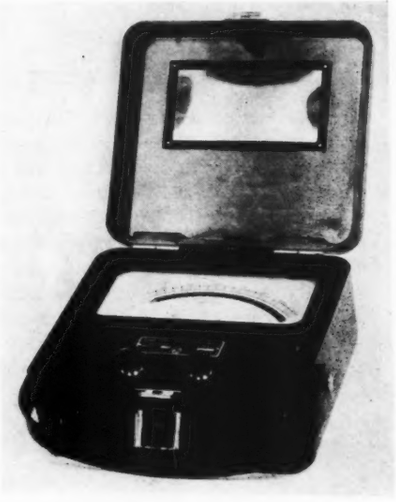
For detecting strains in glass, this analyzer utilizes not only the distortion of polarized light by a strained media, but in addition makes use of the birefringent properties of a system of thin quartz wedges. Light from any convenient source is passed in succession through a polarizing screen, the specimen to be tested, a quartz wedge combination, and finally through an analyzing screen. The direction of the stress and its magnitude can be determined by substituting for the specimen an unstrained rod or cylinder of the same material, loaded with selected weights. General Electric Co., Schenectady, N. Y.

Circuit Breaker

New line of low cost non-industrial circuit breakers designed to meet the demand for a smaller, more compact device for service entrance, range or hot water heater circuits and general purpose use. To be known as Type "M" Multi-breakeR, available in 2 and 3-wire solid neutral with either grounded or insulated neutrals, for 115, 115/230 volts a.c. service. Capacities include 15, 20, 25, 35 and 50 ampere. The tripping action of the 3-wire devices is individual, but the operating handles may be tied together. Box size is 9¼x5x3 in. and may be had for either flush or surface mounting. Square D Co., Detroit, Mich.

Portable Pyrometer

New millivoltmeter-type portable indicating pyrometer for measuring temperatures up to 3,000 deg. F., using a thermocouple and extension leads. Increased sensitivity and a widened scale for more accurate readings is obtained by the use of a cobalt magnet. The high-resistance millivoltmeter movement is double-pivoted and completely shielded to prevent the effects of stray fields. The molded plastic case is moisture and dust-proof. The instrument is available in single and double ranges. The Bristol Co., Waterbury, Conn.



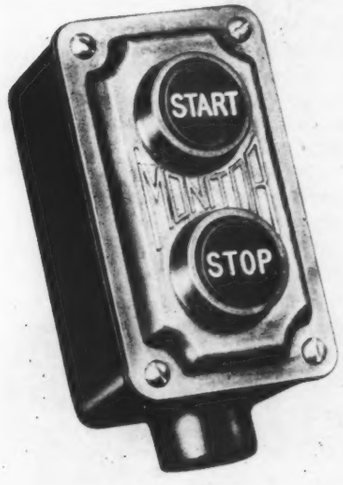
Automatic Electronic Voltage Regulators

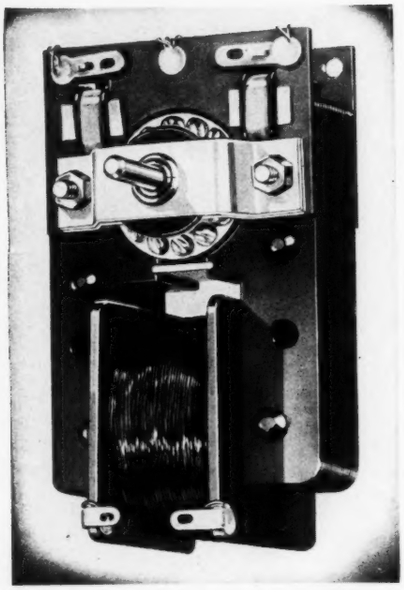
Type EF and Type EB electronic alternator voltage regulators which contain no moving parts. An inertialess stream of electrons controls the regulating action. Power is derived from the a.c. generator and delivers the rectified d.c. current to the shunt field of the exciter in an amount which is a function of the a.c. generator potential. The corrective action of Type EF regulator, illustrated, starts within one-half cycle (1/120 sec.) of the slightest change in generator voltage and Type EB regulators start within one cycle (1/60 sec.). Type EF is designed with an isolated supply transformer making the larger capacities more

easily arranged for switchboard mounting. It can be used with any known method of excitation. Type EB is designed for use with one exciter only. Ward Leonard Electric Co., Mount Vernon, N. Y.

Pushbutton Control Station

With pure silver contacts, mounted on a molded plastic base. Box and cover are die-cast with the box tapped for conduit entrance. Wiring is done by removing the cover without disturbing conduit connections. Colored molded plastic buttons have markings to designate functions, a wide number of contact arrangements being available for almost every industrial purpose. Monitor Controller Co., Baltimore, Md.





Miniature Induction Motor

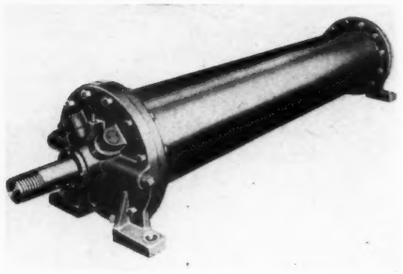
New fractional horsepower motor available in both unidirectional and reversible models. Offers a compact driving source of 1/1000 to 1/100 hp. Journaled in graphited bronze bearings, surrounded by large oil reservoirs for long, noiseless life. Energy transfer can be engineered to fit specific requirements. Alliance Mfg. Co., Alliance, Ohio.

Duplicating Machine

Rotary type, hand-operated duplicating machine, known as the "Ditto R-4 Rotary," which it is claimed can reproduce as many as 150 copies from one original on sheets up to 8½x14 in. Is self-feeding and self-ejecting, resulting in high speed of operation. Copies can be made in as many as eight different colors at one time from typewritten copy or charts or drawings done in ink or pencil, or in a combination thereof. The cost of operation is said to be less than 5 cents per 100 copies. Ditto, Inc., Harrison & Oakley Blvd., Chicago, Ill.

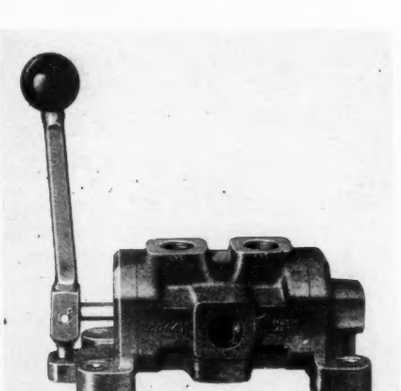
Heavy-Duty Air Cylinder

New "LO" series extra-heavy type air cylinder especially adapted to steel mill and other heavy-duty applications. Cylinders are honed to produce a mirror finish bore that is straight, round and concentric within 0.001 in. The flanges of the cylinders are screwed on and then welded to the cylinder body. Heads are cast steel and are available with or without air cushion at either or both ends. Available in a full range of standard sizes up to 16 in. bore for any length stroke and for air pressures up to 250 lb. per sq. in. Hannifin Mfg. Co., 621 S. Kolmar Ave., Chicago, Ill.



"Carstenite" Paneling

A durable, low cost, decorative panel having a surface of real wood bonded to fiber board with a waterproof synthetic resin. Intended for furniture and all interior decorative purposes where it is desired to show attractive wood surfaces at moderate cost. Is easily sawed and mitred and may be glued or nailed direct. Furnished in 21 different cabinet veneers. Available in widths of 4 ft. and lengths of 4 ft., 6 ft., 8 ft. and 12 ft. Algoma Plywood & Veneer Co., 1236 N. Halsted St., Chicago, Ill.

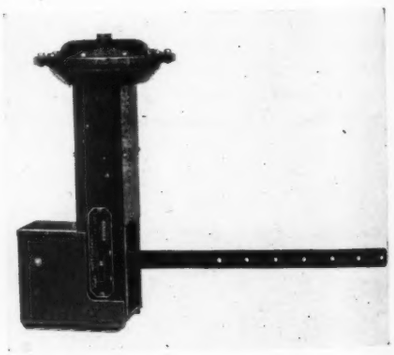


Hydraulic Control Valves

Balanced 4-way piston type, with the body so designed that it may be rotated in relation to the end covers if desired to bring several pipe connections into the position required. No packing is used in the valves except stem seals. Many variations of operation easily secured by rearrangements of the assembly of the valve parts. Available in a complete line to meet practically all hydraulic requirements for hand or semi-automatic control. Sizes range from ¼ in. to 2 in. and for maximum pressure of 1,500 lb. per sq. in. Logansport Machine Inc., Logansport, Ind.

Motosteel Lever Motor

An all-steel welded construction for maximum strength, lightness of weight and permanency of alignment, known as the Motosteel Evenaction pneumatically operated lever motor. For operation of dampers, lever-operated valves, butterfly valves, electrical rheostats for variable-speed motors, for the control of electrical equipment and for the operation of any device by the conversion of pneumatic energy to linear or angular mechanical motion. Precision operation characteristics assure a uniform relation between the air pressure applied to the diaphragm motor and the resulting level travel throughout its stroke. May be operated by remote manual control, an electro-pneumatic switch or a pneumatically-operated controller. Also may be operated in parallel with a diaphragm valve or other pneumatic equipment. Base is drilled for mounting. Three sizes of lever motors are available. Taylor Instrument Companies, Rochester, N. Y.



Leadleaf Paints

A new metallic lead pigment which when mixed with suitable vehicles gives excellent protection against corrosion by forming a thin protective sheet of pure lead. Applied to meal, concrete and wood surfaces, the leadleaf coating is resistant to not only extreme weather conditions and temperatures up to 500 deg. F., but is also resistant to sulphur dioxide gases and solutions, sulphuric acid solutions up to 25 per cent concentration, hydrogen sulphide gases, alkali solutions up to 10 per cent concentration,

and all concentrations of solutions of copper sulphate, zinc sulphate, iron sulphate and brine. It is lead-gray in color and can be used either as a priming coat or a finished coat. Will adhere to new galvanizing without preparing the surface by acid treatment or weathering and is especially recommended as a priming coat under aluminum paints. It can be sprayed, brushed or used in dip tanks provided with agitators. Metalead Products Corp., Balfour Bldg., San Francisco, Calif.

Recalibrator Gage

Indicating gages and thermometers equipped with an adjusting screw for accurately recalibrating them. When an indicating gage or dial thermometer is knocked out of adjustment this condition is usually caused by disrupting the proper relation of the bourdon tube tip to the movement mechanism. Merely removing the hand from the staff and replacing it at what is assumed to be the proper position will not re-establish this relation. Nor will merely revolving the hand on its staff re-establish this relation. In the recalibrator gage, with no pressure or vacuum on the instrument,

the screw is turned until the hand is at zero position, making the instrument accurate at all points. Accuracy in setting dial thermometers is obtained by comparison with another thermometer of known accuracy and revolving the calibrator screw until the indicating hand is at the proper temperature. The calibrator is available in front and back types. Jas. P. Marsh Corp., 2073 Southport Ave., Chicago, Ill.

Manufacturers' Publications

ALLOYED CAST IRONS—The International Nickel Co., Inc., 67 Wall St., New York, N. Y. Nickel Cast Iron Data, Section 1, No. 6. 20 pages, 8½x11 in. Entitled "Alloyed Cast Irons in Petroleum Refining Equipment," containing comparative service data and useful information on properties of numerous cast irons and recommendations of suitable cast iron compositions for typical refinery installations.

BAKELITE—Bakelite Corp., 247 Park Ave., New York, N. Y. Booklet, 16 pages, 3½x6¼ in. "The Versatile Service of Bakelite Materials" presents the story of the development of various bakelite resinous materials, their general characteristics, properties and applications.

BEARINGS—The Fast Bearing Co., Baltimore, Md. Catalog, 15 pages, 8½x11 in. Describing Fast's precision oil film bearings, method of operation, selection, and tables of dimensions and load capacities.

BELT CONVEYORS—Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis. Catalog No. 270, 114 pages, 8 x 10½ in., spiral binding. Combined catalog of equipment and engineering data book "How to Handle It With Rex Belt Conveyors." Contains complete information on the design and application of belt conveyors for handling bulk materials, with listing of belt conveyor equipment.

BROWN ANALY-GRAPH—The Brown Instrument Co., Wayne & Roberts Ave., Philadelphia, Pa. Folder No. 92-2. "Standardizes Quality in the Heat-Treatment of Metals" describes the advantages of using the Brown Analy-graph in heat-treating processes. Also includes data on the Brown Protectoglo (combustion safeguard) system.

BUFFS AND COMPOSITIONS—Hanson-Van Winkle-Munning Co., Matawan, N. J. Bulletin BC-104, 20 pages, 8½x11in. Illustrating various types of buffs and compositions with data on their uses.

COLMONOY ALLOYS—Colmonoy Inc., Los Nietos, Calif. Catalog, 16 pages, 3¾x9 in. General information and application data on Colmonoy alloys and overlay metals, resistant to wear, corrosion and heat.

ELECTRICAL EQUIPMENT—Ideal Commutator Dresser Co., Sycamore, Ill. Catalog, 76 pages, 7¾x10 in. Completely revised reference book including new developments, improvements and additions to Ideal line of products. Interesting data on electrical and motor maintenance included.

ELECTRIC DEVICES—Trumbull Electric Mfg. Co., Plainville, Conn. Catalog 101, 81 pages, 8½x11 in. Covering safety switches, meter service and entrance switches, panel boards, multi-breakers, meter troughs, magnetic motor control and starter equipment, knife switches, fuse blocks and solderless connectors. Includes data on apparatus dimensions, knockout locations, motor ampere ratings, wiring and schematic diagrams, with illustrations and notes on flexible distribution system specialties for industrial use.

ELECTRICAL STEEL SHEETS — Carnegie-Illinois Steel Corp., Pittsburgh, Pa. Bulletin No. 1, 32 pages, 8½x11 in. Latest factual information on "USS Electrical Steel Sheets." An introductory section tells the history of the development, followed by a reference section devoted to an explanation of terms commonly used by electrical engineers and designers. Ten grades of electrical sheets are discussed in reference to their many applications. Striking photographs and photomicrographs illustrate operations with and applications of electrical steel sheets.

ELECTROPLATING—E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. Bulletin, 16 pages, 8½x11 in. "Solution Control for Electroplating" presents a brief review on electroplating, discussing the present need for scientific analytical control.

ETHYL CELLULOSE—Hercules Powder Co., Inc., Wilmington, Del. Booklet, 16 pages, 8½x11 in. Field of application and the basic properties of ethyl cellulose are described.

FINISH—Hilo Varnish Corp., 42-60 Stewart Ave., Brooklyn, N. Y. Methods Bulletin M-A, Third Edition, 8 pages, 5x7½ in. Useful facts on storing, mixing and reducing of various decorative protective coatings.

FLEXIBLE COUPLINGS—The T. L. Smith Co., 2835 N. 32d St., Milwaukee, Wis. Bulleting No. 179, 4 pages, 8½x11 in. Describes the construction and operation of the Rybeck flexible coupling and explains how to installl it. Tables of dimensions and capacities are included and the method of selecting the proper size required for a given service.

FLEXIBLE TUBING AND FITTINGS—Seamlex Co., 5-19 48th Ave., Long Island City, N. Y. Descriptive leaflet, Bulletin 365, 8½x11 in. Covering recently introduced flexible, seamless, all-metal "Triple Safe Tubing" and solderless, brazeless, packless fittings for it. Includes dimensions and maximum working pressures for standard sizes.

GRAPHIC INSTRUMENTS—The Esterline-Angus Co., Indianapolis, Ind. Catalog 237, 88 pages, 8¾x11¼ in. Data on latest graphic instruments in which 24 different measuring elements are available. Descriptive data, design of instrument cases, method of driving the chart, design and construction of meter elements, special attachments, detailed specifications, etc., are covered.

LUBRICATING EQUIPMENT—Gits Bros Mfg. Co., 1859 S. Kilbourn Ave., Chicago, Ill. Presenting latest features of their line of lubricating devices. More than 1,000 styles and sizes of oil cups, oil and grease seals, oil cans, gages, etc., are shown.

MEASURING TAPES AND RULES—The Lufkin Rule Co., Saginaw, Mich. "Engineers Tape and Rule Booklet No. 2," 45 pages.

3½x6¼ in. A comprehensive listing of measuring tapes. tape-rules and other rules of use to engineers, surveyors, road builders, and the oil industry.

MOLDING MATERIAL—Resinox Corp., 230 Park Ave., New York, N. Y. Booklet, 24 pages 6x9 in. A well-illustrated booklet showing the various types of materials that can be molded from Resinox powders, an explanation of how Resinox molding powders are made and a brief outline on mold design, molding operations, mass production and mass acceptance of plastic products.

MOTORS—Century Electric Co., 1806 Pine St., St. Louis, Mo. Form 1033, 8 pages 8x10½ in. Illustrating direct-current motors in sizes ranging from 1 to 300 hp.

SHIMS—Laminated Shim Co., Inc., 21-24 44th Ave., Long Island City, N. Y. Booklet, 16 pages, 8½x11 in. An attractive presentation on Laminum precision adjustment shims and their applications.

SOLENOID STARTERS—Allen-Bradley Co., 1315 S. First St., Milwaukee, Wis. Booklet, 24 pages, 8½x11 in. "The Story of the Solenoid Starter" is briefly told by means of questions and answers in the first section of the booklet, followed by numerous typical application pictures of solenoid motor control and a brief listing of the Allen-Bradley line.

SPROCKETS—The Whitney Chain & Mfg. Co., Hartford, Conn. Catalog V-125, 96 pages, 8½x11 in. Latest price list and reference guide on Whitney stock and made-to-order sprockets. Also includes condensed information on chain selection.

STEELS—Ludlum Steel Co., Watervliet N. Y. Booklet, 143 pages, 5½x7¾ in. Useful facts, charts and conversion tables for tool steels, stainless steels, nitralloy steels and special steels are included in "Fine Steels by Ludlum." Thirty pages of reference tables are included.

SWITCHES—Durakool, Inc., Elkhart, Ind. Bulletin No. 500, 8 pages, 8½x11 in. "The Mercury Switch of Tomorrow" is the title of this bulletin containing general information on Durakool switches. Bulletin No. 501 covers their operating characteristics and application data.

TEMPERATURE AND PRESSURE INSTRUMENTS—C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y. Catalog No. 1060C, 58 pages, 8½x11 in. Presents information on the latest Tag developments, many of which have never before been published. Complete data included on indicating and recording controllers for temperature and pressure, recording thermometers, recording pressure gages and dial indicating thermometers. Many interesting installation pictures as well as pictures showing the operation of the instruments are also included.

VOLTAGE REGULATORS—American Transformer Co., 178 Emmet St., Newark, N. J. Bulletin 1176, 16 pages, 8½x11 in. Covering line of "Transtat" voltage regulators. Includes complete descriptive data, illustrations, circuit diagrams and applications on the new Type TH regulator for controlling a.c. circuits of relatively low voltage and limited capacity.

Books and Bulletins

Gear Cutting Practice

FRED H. COLVIN AND FRANK A. STANLEY. *344 pages, 6x9 in. Blue cloth-board covers. 193 illustrations, 52 tables. Published by McGraw-Hill Book Co., Inc., 330 West 42d St., New York, N. Y. Price $3.*

Written to be a practical guide in gear-cutting practice, the authors describe and illustrate current methods for making gears of all kinds, with many descriptions of equipment used, not only for cutting but also in the finishing and the heat-treating processes.

The book presents complete information covering the standard nomenclature used for gear tooth parts, the types of gears, and the methods of measurement. Much space is given to discussing the characteristics of the various materials used for gears. The principles of milling, hobbing and shaping all types of gears with typical machine setups are treated in full with production data. The machines used for gear and spline cutting are also illustrated and described. Chapters are included which cover burnishing, shaving, lapping, grinding, and heat-treatment; also inspection methods and equipment.

Numerous tables are included which list dimensional units for tooth parts, indexing constants, machine feeds and speed, also rules and formulas.

Man in a Chemical World

A. CRESSY MORRISON. *292 pages, ¾x9¼ in. Blue Clothboard covers. Published by Charles Scribner's Sons, 597 Fifth Ave., New York, N. Y. Price $3.*

A fascinating account of the usefulness of the chemical industry to the people. It is a straight-forward account of the activities of the chemical industry in converting the discoveries of science into the daily necessities of life, written in a highly entertaining and stimulating style.

The author is well-known for his many contributions to the chemical industry and summarizes the part played by this industry in furnishing the materials essential to civilization and progress. Many leading industrialists contributed in reviewing the material presented which gives double assurance of its accuracy and authority.

Typical of its table of contents are chapters that historically portray the growth of the chemical industry, the chemical compounds that it has developed for the control and cure of diseases, its contributions to agriculture and the food industries. Included also are discussions of its innumerable contributions to the fields of product manufacture, such as the development of rubber in which its life and durability was increased fourfold, the development of various types of papers, photograph films and the materials used in telephonic communication and television.

The book is written so that the layman can well understand it and receive an appreciation of the extent to which the progress of civilization is indebted to the chemical industry.

• • •

Engine Bearing Service Manual

ALBERT B. WILLI. *32 pages, 8½x10½ in. Illustrated. Published by the Federal-Mogul Corp., 4809 John R St., Detroit, Mich.*

A comprehensive, non-technical service manual on how to diagnose and correct engine troubles caused by worn or cracked bearings. It discusses the various engine troubles caused wholly or in part by defective engine bearings, such as oil pumping, knocking, sluggishness, etc. However, it does not try to promote the sale of replacement bearings by offering them as a cure-all for a multitude of engine troubles. Related operations necessary to check the cause of defects, such as electrical and carburetion system examination, are described.

The newer designs of engine bearings and the new bearing alloys developed for modern, high-speed engines are also covered.

Although prepared for the practical service man, the book should prove of interest to designers and engineers.

Health Protection of Welders

27 pages, 5½x7¾ in. Published by the Industrial Health Section, Metropolitan Life Insurance Co., 1 Madison Ave., New York, N. Y.

A rather complete compilation of present-day information on health hazards connected with welding operations. It discusses the types of welding and lists four principal hazards that are encountered: (1) electric shock and burns, (2) radiant energy, (3) gases, fumes and dust, (4) miscellaneous, which includes such hazards as the possible exhaustion of oxygen in the air breathed due to pollution by products of combustion in confined, unventilated spaces. These various hazards are discussed in detail and protective measures are outlined. Methods of treatment are also considered.

PRODUCT ENGINEERING + REFERENCE BOOK SHEET

Formulas for Circular Rings

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RAYMOND J. ROARK
Professor of Mechanics, University of Wisconsin

THE FORMULAS published in this and the two preceding issues of *Product Engineering*, as was pointed out in the introduction to the series, are convenient for calculating the stresses and deflections in circular rings since, by superposition, a limited number of such formulas can be combined to cover almost any condition of loading and support likely to occur.

On the following pages are the equations completing the table. Besides the 25 cases presented, showing various conditions of loading and support, there is another case which should be mentioned and which may be regarded as Case 26. This, shown in Fig. 2, was not included in the table because all moments are equal to zero and equations are therefore unnecessary.

Inasmuch as the series is concluded in this issue, two examples are given below to illustrate the use of the formulas and the way in which they may be combined by superposition.

EXAMPLE I: A pipe, diameter 13 ft., thickness ¼ in., is supported at intervals of 44 ft. by rings, each ring being supported at the extremities of its horizontal diameter by vertical reactions acting at the centroids of the ring sections. These, in fact, are the approximate dimensions of a pipe line built at Atrafors, Sweden. It is desired to calculate the maximum bending moment in a supporting ring, the pipe being assumed full of water.

This problem comes under Case 20 (see following page). Taking the weight of water as 62.4 lb. per cu. ft., the weight of the shell as 10.2 lb. per sq. ft., and noting that the maximum moment occurs at $X = 1.166$ radians or 66.8 deg., we have:

$$W = (62.4 \times \tfrac{1}{4} \times \pi \times 13^2 \times 44) + (10.2 \times \pi \times 13 \times 44)$$
$$= 382{,}400 \text{ lb.}$$
$$\text{Max. } M = 0.01456 \times 382{,}400 \times 13/2 \times 12$$
$$= 434{,}000 \text{ in.-lb.}$$

There is a moment of +434,000 in.-lb. at $X = 66.8$ deg. and at $X = 293.2$ deg. in the lower half of the ring, and a moment of —434,000 in.-lb. at $X = 113.2$ deg. and at $X = 246.8$ deg. in the upper half of the ring.

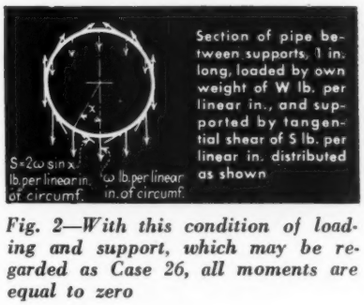

Section of pipe between supports, 1 in. long, loaded by own weight of W lb. per linear in., and supported by tangential shear of S lb. per linear in. distributed as shown
S=2ω sin x lb. per linear in. of circumf.
ω lb. per linear in. of circumf.

Fig. 2—With this condition of loading and support, which may be regarded as Case 26, all moments are equal to zero

By applying the vertical reactions outside the ring at a distance H from the centroid of the ring section, side couples, each equal to $\frac{1}{2}WH$, would be introduced. If H is properly chosen, the effect of these couples (found by the formulas for Case 3) is to reduce the maximum moments in the ring, and it can be shown that by making $H = 0.04R$ optimum conditions are obtained.

EXAMPLE II: Suppose a pipe of the same dimensions, without stiffening rings, is laid on soft ground into which it sinks so as to be in contact over an arc of 60 deg. at the bottom. Assume that the supporting pressure of the earth is radial and uniform over the area of contact. Determine the bending moment per linear inch along bottom element of pipe when it is filled with water.

Consider a 1-in.-long section of the pipe. As shown by Fig. 3, it is loaded by the water with which it is filled and also by its own weight and is supported by a uniformly distributed radial reaction symmetrically located with respect to the base. Reference to the various cases given in the table will not reveal one similar to Fig. 3; hence it is necessary to resort to superposition.

This condition of loading and support may be regarded as a combination of the conditions shown in Figs. 4 and 5. Now, it will be noted that Fig. 4 may be regarded as Case 19 (pipe filled with liquid and supported at base) plus Case 17 (ring loaded by its own weight and supported at base). Moreover, Fig. 5 is the same condition as that shown in Case 14. The problem, therefore, can be solved by superposition of the formulas in these three cases.

First it is necessary to determine the reaction F in Fig. 4, which is equal to the load in Fig. 6. For water, $K = 0.0361$ lb. per cu. in. For a steel shell ¼ in. thick, w (Case 17) $= 0.0708$ lb. per linear in. Then the total weight of the water and of the ring will be:

$$F = K\pi R^2 + 2\pi R w$$
$$= 0.0361\pi(78)^2 + 2\pi(78) \times 0.0708$$
$$= 690 + 34.7$$
$$= 725 \text{ lb.}$$

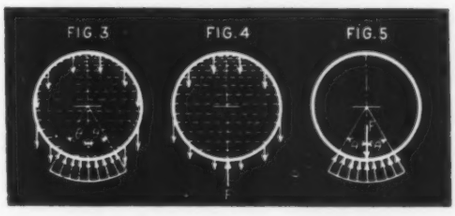
Since $\theta = 30$ deg. $= 0.524$ radians, the uniformly distributed reaction for Fig. 5 and for the formulas of Case 14 is:

$$w \text{ (Case 14)} = \frac{F}{2R \sin\theta} = \frac{725}{2 \times 78 \times 0.5}$$
$$= 9.3 \text{ lb. per in.}$$

Knowing this value and remembering that $C = \cos\theta = 0.866$, we can now solve the equation:

$$M = M_1 \text{ (Case 19)} + M_1 \text{ (Case 17)} + M_1 \text{ (Case 14)}$$
$$M_1 \text{ (Case 19)} = (3/4)\,K R^3 = (3/4)\,(0.0361)\,(78)^3$$
$$= 12{,}860 \text{ in.-lb.}$$
$$M_1 \text{ (Case 17)} = (3/2)\,w R^2 = (3/2)\,(6.0708)\,(78)^3$$
$$= 644 \text{ in.-lb.}$$
$$M_1 \text{ (Case 14)} = w R^2 [C - 0.3183 \times (\theta C - \theta) - 1]$$
$$= 9.3\,(78)^2\,[0.866 - 0.3183\,(0.524 \times 0.866 - 0.524) - 1]$$
$$= -6{,}330 \text{ in.-lb.}$$
$$\text{Therefore, } M = 12{,}860 + 644 - 6.330 = 7{,}170 \text{ in.-lb.}$$

Obviously so thin a pipe could not withstand this great a moment per in., and so the method of support assumed would not be practical.



Formulas for Circular Rings

(*Continued from page 332, August issue*)

LOADING AND SUPPORT

Bending moment M, circumferential tension T, radial shear I at angular distance X from bottom of ring and for D_x change in horizontal diam., and D_y change in vertical diam.

16

$$(X=0 \text{ to } X=\theta)\ M=WR\left\{0.15915\,[S\theta+C-N\phi-H+U\,(S^2-N^2) - Z\,(SC+\theta+NH+\phi)-X\,(S+N)]-\frac{1}{2}\,(S-N)+Z\right\}$$

$$(X=\theta \text{ to } X=2\pi-\phi)\ M=WR\left\{0.15915\,[S\theta+C-N\phi-H+U\,(S^2-N^2) - Z\,(SC+\theta+NH+\phi)-X\,(S+N)]+\frac{1}{2}\,(S+N)\right\}$$

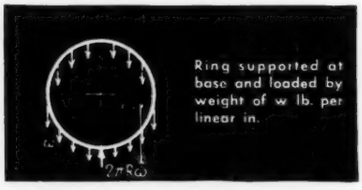
$$(X=2\pi-\phi \text{ to } 2\pi)\ M=WR\left\{0.15915\,[S\theta+C-N\phi-H+U\,(S^2-N^2)-Z\,(SC+\theta+NH+\phi)-X\,(S+N)]+\frac{1}{2}\,(S+3\,N)+Z\right\}$$

$$(X=0 \text{ to } X=\theta \text{ and } X=2\pi-\phi \text{ to } X=2\pi)\ T=W\,[0.15915\,(US^2-UN^2-ZSC-Z\theta-ZNH-Z\phi)+Z]$$

$$(X=0 \text{ to } X=\theta \text{ and } X=2\pi-\phi \text{ to } X=2\pi)\ V=W\,[0.15915\,(-S-N-ZS^2+ZN^2-USC-U\theta-UNH-U\phi)+U]$$

$$(X=\theta \text{ to } X=2\pi-\phi)\ T=W\,[0.15915\,(US^2-UN^2-ZSC-Z\theta-ZNH-Z\phi)];\ V=W\,[0.15915\,(-S-N-ZS^2+ZN^2-USC-U\theta-UNH-U\phi]$$

17

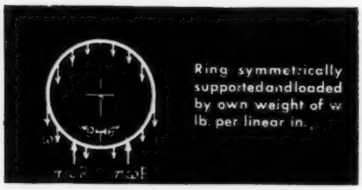


$$M=wR^2\left(1+\frac{1}{2}\,U-\pi Z+XZ\right);\quad T=wR\left(XZ-\frac{1}{2}\,U-\pi Z\right)\qquad V=wR\left(XU+\frac{1}{2}Z-\pi U\right)$$

$$\text{Max.}+M=M_1=\frac{3}{2}\,wR^2\qquad \text{Max.}-M=-0.642\,wR^2 \text{ at } X=1.3\ (74.6°)$$

$$D_x=\frac{wR^4}{EI}\,(0.4292)\qquad D_y=-\frac{wR^4}{EI}\,(0.4674)$$

18



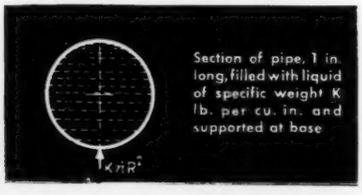
$$M_1=wR^2\left[\frac{1}{2}+C+\theta S-\pi S+S^2\right]\qquad T_1=wR\left[(S^2-\frac{1}{2}\right]$$

$$(X=0 \text{ to } X=\theta)\quad M=M_1-T_1R\,(1-U)+wR^2\,(XZ+U-1)$$
$$(X=0 \text{ to } X=\theta)\quad T=T_1U+wRXZ$$
$$(X=0 \text{ to } X=\theta)\quad V=-T_1Z+wRXU$$

$$(X=\theta \text{ to } X=\pi)\quad M=M_1-T_1R\,(1-U)+wR^2\,(XZ+U-1-\pi Z+\pi S)$$
$$(X=\theta \text{ to } X=\pi)\quad T=T_1U+wR\,(XZ-\pi Z)$$
$$(X=\theta \text{ to } X=\pi)\quad V=-T_1Z+wR\,(XU-\pi U)$$

$$D_x=\frac{wR^4}{EI}\left[\frac{1}{2}\,\pi\,(1+S^2-4\,S)+2\,(\theta S+C)\right]\qquad D_y=\frac{wR^4}{EI}\left[-2.4674+\frac{1}{2}\,\pi\,(SC+\theta-2\,S)+2\,(\theta S+C)\right]$$

19



$$M_1=\frac{3}{4}\,KR^3\qquad T_1=\frac{5}{4}\,KR^2$$

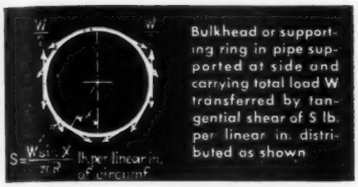
$$M=KR^3\left[\frac{1}{2}+\frac{1}{4}U-\frac{1}{2}\pi Z+\frac{1}{2}\,XZ\right]\qquad T=KR^2\left[1+\frac{1}{4}\,U-\frac{1}{2}\pi Z+\frac{1}{2}\,XZ\right]$$

$$V=KR^2\left[\frac{1}{2}\,XU+\frac{1}{4}\,Z-\frac{1}{2}\pi U\right]$$

$$D_x=\frac{KR^5}{EI}\,(0.2146)\qquad D_y=-\frac{KR^5}{EI}\,(0.2337)$$

$$\text{Max.}+M=M_1\qquad \text{Max.}-M=-0.321\,KR^3 \text{ at } X=1.3\ (74.6°)$$

20



Bulkhead or supporting ring in pipe supported at side and carrying total load W transferred by tangential shear of S lb. per linear in. distributed as shown

$M_1 = -0.01132\ WR \qquad T_1 = -0.07958\ W$

$D_x = 0 \ ; \quad D_y = 0$

M at $X = -M$ at $(\pi - X)$

$M = 0$ at $X = \pi/2$

$(X=0 \text{ to } X=\pi/2) \quad M = WR\ (0.23868\ U + 0.15915\ XZ - \frac{1}{4})$

$(X=0 \text{ to } X=\pi/2) \quad T = W\ (0.15915\ XZ - 0.07958)$

$(X=0 \text{ to } X=\pi/2) \quad V = W\ [0.15915\ (X\,U - Z)]$

$(X=\pi/2 \text{ to } X=\pi) \quad M = WR\ (0.23868\,U + 0.15915\,XZ - \frac{1}{2}Z + \frac{1}{4})$

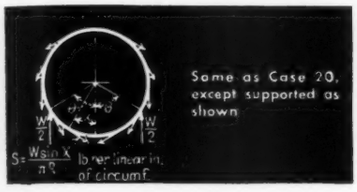
$(X=\pi/2 \text{ to } X=\pi) \quad T = W\ (0.15915\,XZ - 0.07958 - \frac{1}{2}Z)$

$(X=\pi/2 \text{ to } X=\pi) \quad V = W\ [0.15915\ (X\,U - Z) - \frac{1}{2}U]$

Max. $+\ M = 0.01456\ WR$ at $X = 1.166\ (66.8°)$

Max. $-\ M = -0.01456\ WR$ at $X = 1.975\ (113.2°)$

21



Same as Case 20, except supported as shown

$(X=0 \text{ to } X=\theta) \quad M = WR\ [0.23868\ U - \frac{1}{2}S + 0.15915\ (XZ + \theta S + C - UC^2)]$

$(X=0 \text{ to } X=\theta) \quad T = W\ [0.15915\ (XZ - UC^2) - 0.07958]$

$(X=0 \text{ to } X=\theta) \quad V = W\ [0.15915\ (X\,U - Z + ZC^2)]$

$(X=\theta \text{ to } X=\pi) \quad M = WR\ [0.23868\ U - \frac{1}{2}Z + 0.15915\ (XZ + \theta\,S + C - UC^2)]$

$(X=\theta \text{ to } X=\pi) \quad T = W\ [0.15915\ (XZ - UC^2) - 0.07958 - \frac{1}{2}Z]$

$(X=\theta \text{ to } X=\pi) \quad V = W\ [0.15915\ (X\,U - Z + ZC^2) - \frac{1}{2}U]$

$$D_x = \frac{WR^3}{EI}\left[0.3183\ (S\theta + C) - \frac{1}{4}\ (S^2 + 1)\right]$$

$$D_y = \frac{WR^3}{EI}\left[0.3183\ (S\theta + C) + \frac{1}{4}\ (SC + \theta) - \frac{1}{2}\,S - \pi/8\right]$$

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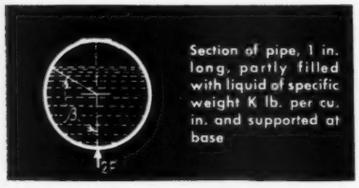

Section of pipe, 1 in. long, partly filled with liquid of specific weight K lb. per cu. in. and supported at base

$$M_1 = KR^3\left[0.6366\ (\tfrac{1}{2}\beta Q - \tfrac{3}{8}\beta - \tfrac{1}{2}P + \tfrac{5}{8}PQ - \tfrac{1}{4}\beta Q^2) + Q^2 - Q + \tfrac{1}{2}P^2\right] + 0.6366\ FR$$

$$T_1 = w\,R^2\left[\tfrac{1}{2}P^2 - Q + Q^2 + 0.3183\ (\tfrac{3}{4}PQ - \tfrac{1}{2}\beta Q^2 - \tfrac{1}{4}\beta)\right] \qquad F = \tfrac{1}{4}\,KR^2\,(2\beta - \sin 2\beta)$$

$(X=0 \text{ to } X=\beta) \quad M = M_1 - T_1R\,(1-U) - FRZ + KR^3\ (\frac{1}{2}XZ - Q + Q\,U)$

$(X=0 \text{ to } X=\beta) \quad T = T_1\,U - FZ + KR^2\ (\frac{1}{2}XZ - Q + Q\,U)$

$(X=0 \text{ to } X=\beta) \quad V = -T_1Z - F\,U + KR^2\ (\frac{1}{2}X\,U + \frac{1}{2}Z - QZ)$

$$(X=\beta \text{ to } X=\pi) \quad M = M_1 - T_1R\,(1-U) - FRZ + KR^3\left[\tfrac{1}{2}Z\,(\beta - PQ) + U\,(Q - Q^2 - \tfrac{1}{2}P^2)\right]$$

$$(X=\beta \text{ to } X=\pi) \quad T = T_1\,U - FZ + KR^2\left[\tfrac{1}{2}Z\,(\beta - PQ) + U\,(Q - Q^2 - \tfrac{1}{2}P^2)\right]$$

$$(X=\beta \text{ to } X=\pi) \quad V = -T_1Z - F\,U + KR^2\left[\tfrac{1}{2}\,U\,(\beta - PQ) - Z\,(Q - Q^2 - \tfrac{1}{2}P^2)\right]$$

$$\text{When } \beta < \tfrac{1}{2}\pi, \quad D_x = \frac{2}{EI}\left[0.1366\,FR^3 + KR^5\ (0.1533\,\beta + \tfrac{1}{8}\beta Q^2 - 0.3183\,P + 0.3183\beta Q - 0.2783\,PQ)\right]$$

$$\text{When } \beta > \tfrac{1}{2}\pi, \quad D_x = \frac{2}{EI}\left[0.1366\,FR^3 - KR^5\ (0.3183\,P - 0.3183\,\beta Q - 0.3467\,PQ + 0.2217\,\beta + Q + \tfrac{1}{8}\beta Q^2 - \tfrac{\pi}{4}\,Q^2 - \tfrac{\pi}{8}\,P^2 - \tfrac{\pi}{16})\right]$$

$$D_y = \frac{2}{EI}\left[-0.1488\,FR^3 - w\,R^5\ (0.1591\,P - 0.4773\,\beta Q + 0.7110\,PQ + \tfrac{1}{16}\,\beta^2 - \tfrac{1}{8}\,\beta PQ - \tfrac{1}{16}\,P^2 - \tfrac{1}{2}\,Q^2 + \tfrac{1}{2}\,Q + \tfrac{1}{4}\,QP^2 - \tfrac{3}{8}\,Q^2P^2 - \tfrac{1}{4}\,P^4 - 0.3927\,\beta)\right]$$

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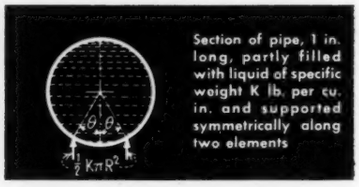

Section of pipe, 1 in. long, partly filled with liquid of specific weight K lb. per cu. in. and supported symmetrically along two elements

$$M_1 = KR^3\left[\frac{1}{4}-\frac{\pi}{2}S+\frac{1}{2}\theta S+\frac{1}{2}C+\frac{1}{2}S\right] \qquad T_1 = KR^2\left[\frac{1}{2}S+\frac{5}{4}\right]$$

$$D_x = \frac{KR^5}{EI}\left[\frac{1}{2}S^2-2S+0.6366\,(\theta S+C)+0.578\right]$$

$$D_y = \frac{KR^5}{EI}\left[\frac{1}{2}SC+\frac{1}{2}\theta+0.6366\,(\theta S+C)-S-0.8703\right]$$

$(X=0 \text{ to } X=\theta)$

$$M = KR^3\left[\frac{1}{4}U+\frac{1}{2}XZ-\frac{1}{2}\pi S+\frac{1}{2}\theta S+\frac{1}{2}C+\frac{1}{2}US^2\right]$$

$$T = KR^2\left[1+\frac{1}{4}U+\frac{1}{2}XZ+\frac{1}{2}US^2\right]$$

$$V = KR^2\left[\frac{1}{2}XU+\frac{1}{4}Z-\frac{1}{2}ZS^2\right]$$

$(X=\theta \text{ to } X=\pi)$

$$M = KR^3\left[\frac{1}{4}U-\frac{1}{2}\pi Z+\frac{1}{2}XZ+\frac{1}{2}\theta+\frac{1}{2}C+\frac{1}{2}US^2\right]$$

$$T = KR^2\left[1+1.8208\,U-\frac{1}{2}\pi Z+\frac{1}{2}XZ-\frac{1}{2}ZS^2\right]$$

$$V = KR^2\left[\frac{1}{2}XU+\frac{1}{4}Z-\frac{1}{2}\pi U-\frac{1}{2}ZS^2\right]$$

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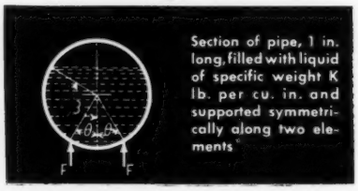

Section of pipe, 1 in. long, filled with liquid of specific weight K lb. per cu. in. and supported symmetrically along two elements

$$M_1 = KR^3\left[0.6366\,(\tfrac{1}{2}\beta Q-\tfrac{3}{8}\beta-\tfrac{1}{2}P+\tfrac{5}{8}PQ-\tfrac{1}{4}\beta Q^2)+Q^2-Q+\tfrac{1}{2}P^2)\right]+ 0.3183\,FR\,(1+C+\theta S-\pi S+S^2)$$

$$T_1 = KR^2\left[\frac{1}{2}P^2-Q+Q^2+0.3183\,(\frac{3}{4}PQ-\frac{1}{2}\beta Q^2-\frac{1}{4}\beta)+\frac{1}{\pi}FS^2\right]; F=\frac{1}{4}KR^2\,(2\beta-\sin 2\beta)$$

$(X=0 \text{ to } X=\theta)$

$$M = M_1 - T_1R\,(1-U)+KR^3\,(\tfrac{1}{2}XZ-Q+QU)$$

$$T = T_1U+0.3183\,FUS^2+KR^2\,(\tfrac{1}{2}XZ-Q+QU)$$

$$V = -T_1Z-0.3183\,FZS^2+KR^2\,(\tfrac{1}{2}XU+\tfrac{1}{2}Z-QZ)$$

$(X=\theta \text{ to } X=\pi)$

$$M = M_1-T_1R\,(1-U)+KR^3\,(\tfrac{1}{2}XZ-Q+QU)-F\,(Z-S)$$

$$T = T_1U+F\,(0.3183\,US^2-Z)+KR^2\,(\tfrac{1}{2}XZ-Q+QU)$$

$$V = -T_1Z-F\,(0.3183\,ZS^2+U)+KR^2\,(\tfrac{1}{2}XU+\tfrac{1}{2}Z-QZ)$$

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$(X=\beta \text{ to } X=\pi)\quad M = M_1-T_1R\,(1-U)+KR^3\,[Z\,(\tfrac{1}{2}\beta-\tfrac{1}{2}PQ)+U\,(Q-Q^2-\tfrac{1}{2}P^2)-F(Z-S)$

$(X=\beta \text{ to } X=\pi)\quad T = T_1U+F\,(0.3183\,US^2-Z)+KR^2\,(\tfrac{1}{2}\beta Z-\tfrac{1}{2}PQZ-\tfrac{1}{2}P^2U-Q^2U+QU)$

$(X=\beta \text{ to } X=\pi)\quad V = -T_1Z-F\,(0.3183\,ZS^2+U)+KR^2\,(\tfrac{1}{2}\beta U-\tfrac{1}{2}PQU+\tfrac{1}{2}P^2Z+Q^2Z-QZ)$

When $\beta < \frac{1}{2}\pi$, $D_x = \frac{2}{EI}\left\{FR^3\left[0.3183\,(1+\theta S+C)+\frac{1}{4}S^2-S\right]-KR^5\left[0.1533\,\beta+\frac{1}{8}\beta Q^2-0.3183\,P+0.3183\,\beta Q-0.2783\,PQ\right]\right\}$

When $\beta > \frac{1}{2}\pi$, $D_x = \frac{2}{EI}\left\{FR^3\left[0.3183(1+\theta S+C)+\frac{1}{4}S^2-S\right]-KR^5\left[0.3183\,P-0.3183\,\beta Q-0.3467\,PQ+0.2217\,\beta+Q+\frac{1}{8}\beta Q^2-\frac{\pi}{4}Q^2-\frac{\pi}{8}P^2-\frac{\pi}{16}\right]\right\}$

$$D_y = \frac{2}{EI}\left\{FR^3\left[0.3183\,(\theta S+C)+\tfrac{1}{4}(SC+\theta)-0.567\right]-wR^5\left[0.1591\,P-0.4773\,\beta Q+0.7110\,PQ+\frac{1}{16}\beta^2-\frac{1}{8}\beta PQ-\frac{1}{16}P^2-\frac{1}{2}Q^2+\frac{1}{2}Q+\frac{1}{4}QP^2-\frac{3}{8}P^2Q^2-\frac{1}{4}P^4-0.3927\,\beta\right]\right\}$$

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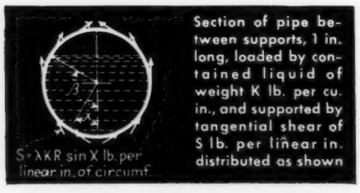

Section of pipe between supports, 1 in. long, loaded by contained liquid of weight K lb. per cu. in., and supported by tangential shear of S lb. per linear in. distributed as shown

$$M_1 = KR^3\left[0.3183\,(\tfrac{5}{4}PQ-\tfrac{3}{4}\beta-\tfrac{1}{2}\beta Q^2-\tfrac{1}{2}P+\beta Q-\tfrac{1}{2}PQ^2-\tfrac{1}{2}P^3)-Q+Q^2+\tfrac{1}{2}P^2+\tfrac{1}{2}\lambda\right]$$

$$T_1 = KR^2\left[0.3183\,(\tfrac{3}{4}PQ-\tfrac{1}{4}\beta-\tfrac{1}{2}\beta Q^2)-Q+Q^2+\tfrac{1}{2}P^2+\tfrac{3}{4}\lambda\right] \qquad V_1=0$$

$(X=0 \text{ to } X=\beta)\quad M = M_1-T_1R\,(1-U)+KR^3\left[\frac{1}{2}XZ-Q+QU-\lambda\,(\frac{1}{2}XZ+U-1)\right]$

$(X=\beta \text{ to } X=\pi)\quad M = M_1-T_1R\,(1-U)+KR^3\left[Z\,(\frac{1}{2}\beta-\frac{1}{2}PQ)+U\,(Q-Q^2-\frac{1}{2}P^2)-\lambda\,(\frac{1}{2}XZ+U-1)\right]$

$\lambda = \dfrac{2\beta-\sin 2\beta}{2\pi}$ = fractional degree of fullness of pipe.

Max. $M_1 = -0.0683\,KR^3$ when $\beta=\pi/2$ (pipe half full).
Max. $T_1 = 2\,KR^2$ when $\beta=\pi$ (pipe full).
NOTE: All moments become zero for $\beta=\pi$, *i.e.*, for pipe completely full